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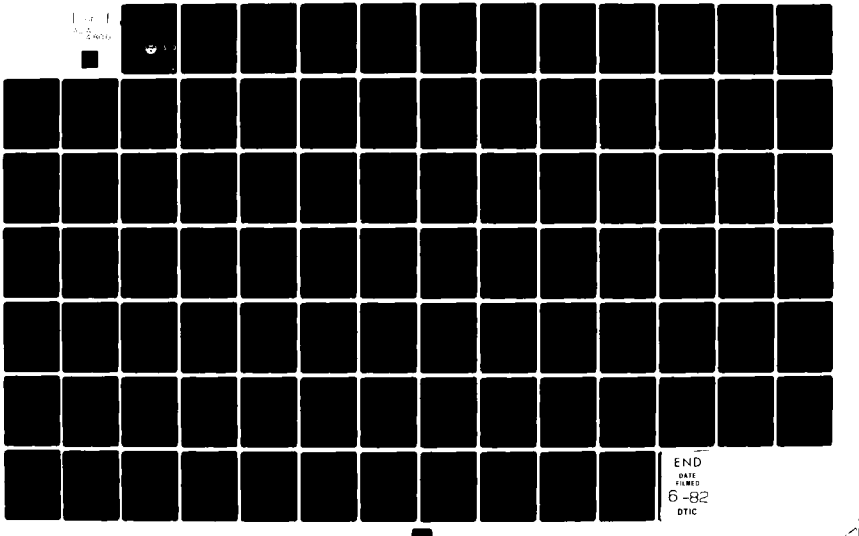

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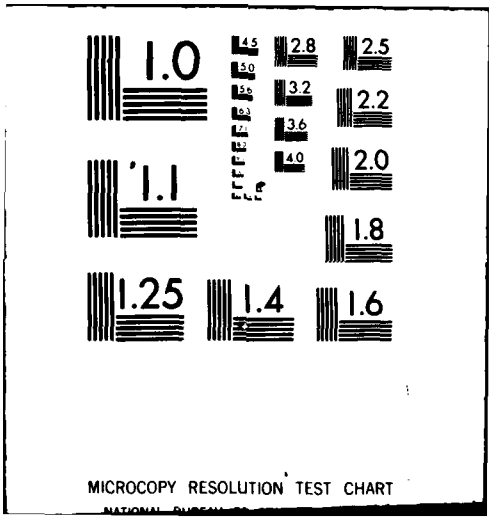
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HUMAN/COMPUTER TRANSACTION TASKS: AN ANNOTATED BIBLIOGRAPHY

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report provides an annotated bibliography of references relating to human/computer transactions. Operator-analyst and software programmer roles are represented by the majority of the references. Topics covered include display formatting, error modeling, performance assessment, query languages, keyboard and data entry, data organization, and speech input/output.

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FOREWORD

This selected annotated bibliography was developed by the Virginia Polytechnic Institute and State University under contract N00123-77-C-1081 in support of project Z1170-PN (Human Processing of Large Automated Data Base), subproject Z1170.PN.03 (improving the accuracy and usability of automated personnel information systems). The work was sponsored by the Deputy Chief of Naval Operations (Manpower, Personnel, and Training, OP-01). The subproject was directed toward resolving fundamental human engineering design issues in systems that contain man/computer interfaces. Preliminary research for this subproject was performed under subproject ZF55-521-001-022, work unit 03.03 (forecasting new task requirements).

This report provides a selected annotated bibliography of technical literature relevant to human/computer transaction tasks. Operator-analyst and software programmer roles are represented by the majority of references. The literature review was completed in June 1978 and results were used at the Navy Personnel Research and Development Center in research to resolve fundamental human engineering design issues for computer systems. The mathematical techniques used in this subproject to project operator performance can be used for other forecasting problems.

The bibliography is being published at this time to make it available to the research community and to others developing systems requiring man/computer interfaces.

The contracting officer's technical representative was Dr. F. A. Muckler.

JAMES F. KELLY, JR.
Commanding Officer

JAMES J. REGAN
Technical Director

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INTRODUCTION

Problem

The area of human/computer interaction constitutes a significant portion of present research in human factors engineering. While many questions still require investigation, a large amount of work has appeared in the literature to date.

Purpose

The purpose of this effort was to provide a bibliography for use by those developing systems containing man/computer interfaces.

Approach

An extensive computerized library literature search of the National Technical Information Service and Psychological Abstracts files was conducted. Only references that are readily available, either in reprint form or from the author, were included in the bibliography.

Results

The resulting annotated bibliography is provided in the appendix. It includes selected references from numerous technical reports, journal articles, and texts relating to human/computer transactions. Operator-analyst and software programmer roles are represented by the majority of the references included. Computer-assisted instruction, computer-managed instruction, and the role of the computer in training are not covered in this bibliography. The references included are concerned primarily with display formatting, error modeling, performance assessment, query languages, keyboard and data entry, data organization, and speech input/output.

Abstracts written by the author of each reference were used where possible. In instances where no formal abstract was available, a brief summary written by the compiler of this bibliography is provided.

APPENDIX

BIBLIOGRAPHY

Abrams, M. D., Lindamood, G.E., and Pyke, T. N., Jr. Measuring and modeling man-computer interaction. Proceedings Annual SIGME Symposium on Measurement and Evaluation (1st), Palo Alto, California, February 26-28, 1973, 136-142.

The Dialogue Monitor has been developed as a tool for the measurement of computer service. The objectives of such measurements are defined. A set of models and measures are developed. Operation of the Dialogue Monitor and analysis of the data obtained are briefly discussed.

Alden, D. G., Daniels, P. W., and Kanarick, A. F. Keyboard design and operation: A review of the major issues. Human Factors, 1972, 14, 275-293.

A search of the psychological, technical, and promotional literature was conducted to compile information relevant to key, keyboard, and operator characteristics. The most recent and significant articles were discussed and evaluated. Where possible, general conclusions have been drawn to aid the keyboard designer.

Alford, E. C. and Buck, J. R. A unit task simulator for off-line evaluation of man/computer interfaces. Proceedings of the International Ergonomics Association, 6th Annual Meeting, Santa Monica California: Human Factors Society, 1976.

A method is shown for simulating individual operator man/computer tasks and collecting performance statistics. This method employs a minicomputer with structured software that receives user-written programs for the specific processes and for display formatting. Users can easily try out and evaluate alternaive interface designs, different combinations of task assignments, or various formatting dialogues. Job and task performance characteristics are directly obtained. An illustration is given. These performance characteristics may be used comparatively or as inputs to a total system simulation for the design of large man/machine systems.

Alluisi, E. A. Methodology in the use of synthetic tasks to assess complex performance. Human Factors, 1967, 9, 375-384.

The application of synthetic tasks to the assessment of complex performance is discussed in relation to the trade-offs involved in achieving adequate levels of face validity and in specifying the exact changes in psychological functions that may result from particular environmental manipulations. It is argued that the multiple-task performance battery approach can provide levels of face validity adequate to maintain the motivation of subjects while at the same time permitting the identification of changes in specific performance functions. The characteristics of this approach are discussed in relation to a program of research on the effects of confinement and demanding workrest schedules on crew performance.

Ambrozy, D. On man-computer dialogue. International Journal of Man-Machine Studies, 1971, 3 (4), 375-383.

Every man-computer interaction involves some kind of dialogue; however it is not yet fully clear what kind of activity can be called a dialogue and how to calculate its simpler parameters. This paper surveys some aspects of the seemingly simple problem and presents a formulation of the dialogue and of the basic human factor influencing its course: the specific fatique associated with the information processing work of the human nervous system.

Atwood, R. and Ramsey, H. R. Cognitive structures in the comprehension and memory of computer programs: An investigation of computer program comprehension debugging. Englewood, Colorado: Science Applications, Incorporated, Report No. SAI-77-194-DEN, October, 1974.

A theoretical framework, based upon recent studies in cognitive psychology on memory for text, was developed to explain certain aspects of human behavior during computer program comprehension and debugging. A central concept of this framework is that the information contained in a program is represented in a programmer's memory as a connected, partially ordered list (hierarchy) of "propositions" (units of information with properties similar to those observed in research on text memory). An experiment was performed to test the hypothesis that the difficulty in finding a program bug is a function of the bug's location in this hierarchy. This experiment, which was based on a paradigm previously used by others, compared the effects of bug location, bug type (array, iteration, assignment) and specific program. Subjects were 48 undergraduate students with a minimum experience level of three computer science courses. Each subject debugged two separate programs, with one type of bug at two different hierarchical levels in each program. A preliminary analysis suggested that all three factors -- program, bug type, and bug location -- significantly affected the time required to locate program bugs. Detailed analyses, however, suggested the program and bug type variables could be explained in terms of the bug location variable and that a bug's location in a program's underlying propositional hierarchy is a principal factor affecting performance in a comprehension and debugging task. The difficulty in detecting a bug is a function of the bug's location in the propositional hierarchy that a programmer constructs to represent a program. Programs should be written so as to avoid unnecessarily deep hierarchies and modularized so as to minimize the number of propositions in a given section in order to facilitate computer program comprehension and debugging. The principal contribution of this research is the demonstration of an initial theoretical framework which, with further development, may assist considerably in the integration of research findings and the guidance of future research on the psychological aspects of software development.

Baker, J. D. Programmed instruction as a methodological tool in psychological research. Journal of Programmed Instruction, 1963, 2 (1), 20-23.

The use of programmed instruction as a methodological tool in psychological research is presented as a means for increasing experimental control. One advantage in using programmed instruction in the orientation and training phase of psychological studies is that it insures controlled presentation of complex instructions for novel experimental tasks which use unique materials. A second advantage is that it reduces to a minimum the personal interaction between experimenter and subject, which could introduce bias into the experiment. It is suggested that an inventory of programs for common experimental tasks would provide a basis for better intrastudy generalization in experimental psychology.

Baker, J. D. Quantitative modeling of human performance in information systems. Ergonomics, 1970, 13, 645-664.

This paper summarizes an approach toward developing a general informatin system model which focuses on man and considers the computer only as a tool. The ultimate objective is to produce a simulator which will yield measures of system performance under different mixes of equipment, personnel and procedures. In structuring the framework for this model the assumption was made that men have five basic and critical operations to perform in an information system: screen, transform, input, assimilate and decide. These operations, or functional areas, are interrelated along three dimensions: (1) a data flow and processing dimension: (2) a task analysis dimension for each event in the data flow sequence; and (3) a source of variation dimension, such as level of training. The model approach described has several major points of payoff. Among the immediate benefit is the potential for using the model to quantify human performance by employing system measures and the value of the model as a tested, usable tool for developing test and evaluation plans which will provide human factors data as part of the information system design verification checkout.

Baker, J. D. How will improvements in man-machine interface affect learning? In R. J. Seidel and M. L. Rubin (Eds.) Computers and communication: Implications for education. New York: Academic Press, 1977, 379-386.

This paper defines information systems and makes suggestions concerning computers-in-education problems, display problems, and man-computer interaction and information transfer.

Baker, J. D., Mace, D. J., and McKendry, J. M. The transform operation in TOS: Assessment of the human component. Arlington, Virginia: U.S. Army Behavioral Science Research Laboratory, Technical Research Note 212, August, 1969.

Forty-seven simple messages were given to 14 individuals familiar with TOS or G3 operations, or both. Their task was to select an appropriate format for each message. Half the men used a simple job aid devised by the experimenters; the other half used a "menu" type listing of available formats. The time taken to complete the entire task was recorded. Individuals also rated the degree of confidence they had that the proper format had been selected. Average error rate in format selection was 22%. Mean time to read the message and select a format was approximately 50 seconds. Performance with the job aid was neither better nor worse than with the menu type listing. Messages of different types and subject matter differed in error rate of format selection. The study provided baseline data with which future performance can be compared. The findings suggested some approaches to training and alternative methods for the transform process.

Barmack, J. E. and Sinaiko, H. W. Human factors problems in computer-generated graphic displays. Arlington, Virginia: Institute for Defense Analyses, Report No. S-234, April, 1966.

This paper reports a review of the state of the art with respect to human factors as applied to interactive graphical computer systems. Information in the report was derived from both a review of the literature and visits to 14 facilities employing such systems. The review is broad in scope, including discussions of: CRT display parameters, display coding, display flicker, three-dimensional displays, and symbols, input devices, including keyboards, character and speech recognition, light pens, and switches; general system properties; and a theoretical discussion of the use of computers to enhance creative effort.

Barrett, G. V., Thornton, C. L., and Cabe, P. A. Human factors evaluation of a computer-based information storage and retrieval system. Human Factors, 1968, 10, 431-436.

The human factors aspects of a computer-based information storage and retrieval system were evaluated in three government intelligence services using questionnaire and interview techniques. It was found that many factors entered into satisfaction with the information system, including familiarity, ease of use, and importance. Other relevant factors included training in the use of the system, amount and type of information to meet need in the system, and tolerances of individuals for irrelevant material in the output of searches. The interaction of these factors is discussed in relation to satisfaction with the system.

Bergman, C. A. An airplane performance control system: A flight experiment. Human Factors, 1976, 18, 173-182.

Pilots performance and preference measures were obtained for 12 pilots in actual flight operations using a twin-engine general aircraft with both conventional controls and a Performance Control System (PCS). The PCS provides zero-order control of aircraft bank angle and vertical speed over the ranges of ±60° and ±457.2 m/min, respectively. An information processing side-task was also used. With the PCS, flight error scores were reliably lower than with conventional aircraft controls. Pilot preferences, using a six-point scale, ranging from "slight" to "moderate" to "strong" preference for each of the two control systems, showed a "moderate preference for the PCS" as the median response.

Berson, B. L., Crooks, W. H., Shaket, E., and Weltman, G. Man-machine communication in computer-aided remote manipulation. Woodland Hills, California: Perceptronics, Technical Report PATR-1034-77-3/1, March, 1977.

Automated Remote Manipulation is both an area of great practical utility for Navy Undersea Operations, and a prime example of new type of man-machine interaction in which the human operator must supervise and control a complex and adaptive man-computer system. This report presents the results of an experimental study focusing on man-machine communication with computer-aided manipulators. This report describes (1) underwater manipulator functions and operator performance requirements in remote manipulation, (2) the development of theoretical man-machine communication model based on procedural sets, and (3) an experimental investigation on the effect of several elementary computer aiding techniques on the ability of training operators to perform selected remote manipulation tasks. The results of the experimental investigation indicated that computer aiding can significantly decrease task performance times for a number of remote manipulation tasks. Computer aiding in the form of resolved motion and automated control significantly reduced the times required to perform valve turning and ring manipulation tasks. The results also indicated that if higher-level aiding schemes are to be effective in terms of improving man-machine performance, the design of the communications language and interface must be carefully designed to maintain the communication goals of naturalness, simplicity and understandability.

Blanchard, R. E. Human performance and personnel resources data store design guidelines. Human Factors, 1975, 17, 25-34.

A survey was conducted within the Navy's research and development community to obtain information on user-perceived needs for human performance and personnel resource data to support system development efforts. Findings were to be used to develop guidelines for planning and developing a human resources data store system. Twenty-two activities were contacted: eighteen Navy activities and four industrial firms. Thirty-seven separate interview sessions were held involving 48 respondents. Principal data store guidelines identified concerned data validity and generalizability, retrievability, a priority need for design trade-off decision data, and a data format responsive to users with either behavioral or engineering backgrounds. Sixteen types of data were identified as required by system planners/managers, human factors specialists, and design engineers. Twenty guidelines were developed on data presentation formats and supporting information. The sets of guidelines may be used to develop a conceptual framework for a general data bank system which would identify and relate users, types of data, potential data sources, and program priorities.

Boies, S. J. and Gould, J. D. Syntactic errors in computer programming. Human Factors, 1974, 16, 253-257.

A study of users of a large-scale computer system (TSS/360) revealed that only 12 to 17% of the FORTRAN, PL1, and Assembler Language computer programs submitted to the language processors contained syntactic errors. Thus, syntactic errors do not appear to be a significant bottleneck in programming. This experiment is part of a larger effort to identify and reduce the behavioral bottlenecks in computer programming.

Bowser, S. E. Determination of criteria of operational unit effectiveness in the U.S. Navy. San Diego, California: Navy Personnel Research and Development Center, Report No. NPRDC TR 76TQ-41, August, 1976.

The criteria for evaluating organizational effectiveness are considered within a system framework. A general review of the literature is presented. Operational unit management personnel were interviewed and this interview material was content analyzed. The resulting content categories were cross compared by unit type, position in the organization, rank of respondent and question answered. The results show military managers to be performance oriented and supportive of objective type criteria for evaluations.

Brown, G. P. A framework for processing dialogue. Cambridge, Massachusetts: Masachusetts Institute of Technology, Cambridge Lab for Computer Science, Report No. MIT/LCS/TR-182, June, 1977.

This report describes a framework for handling mixed-initiative English dialogue in a console session environment, with emphasis on recognition. Within this framework, both linguistic and nonlinguistic activities are modelled by structures called 'methods', which are a declarative form of procedural knowledge. The design focuses on units of linguistic activity larger than the speech act, so that the pragmatic and semantic context of an utterance can be used to guide its interpretation. Also important is the treatment of indirect speech acts, e.g., the different ways to ask a question, give a command, etc. Given the static model of dialogue embodied in the methods, the problem is to find the correct method step that relates to a particular input. This problem is handled through a combination of careful structural distinctions and the use of multiple recognition strategies. The dialogue methods are used to generate expectations dynamically, special structures are used to facilitate matching, and a basic distinction between four major utterance classes is used to determine which of several overall matching strategies should be used for a given expectationn.

Brown, R. M. An experimental study of an on-line man-computer system. IEEE Transactions on Electronic Computers, February, 1965, EC-14, 82-85.

One of the more promising areas of computer use involves the coupling of a man to a computer system for real-time problem solving where the procedure for solution of the problem is either unknown or involves complex tasks, such as pattern recognition, that can best be performed by humans (1). Unfortunately, a straightforward approach to such use commits significant amounts of computer time most of which is spent idling. The imbalance in operating costs, assignable to the human and the computer, argues against computer use unless the total gain over strictly manual operations is sufficiently great. The technique of computer time-sharing, currently under development in several institutions (2), attempts to divide the computer costs among a number of users by interleaving the execution of their programs so as to share the operations time while also minimizing mutual conflicts. The success of this technique rests on a number of assumptions concerning the characteristics of the programs if run alone. This paper defines some properties of on-line programs useful in predicting their performance under time-sharing. It then describes a specific man-machine program and gives experimental measurements on this program. While at this stage of understanding, no man-machine program can be described as "typical," this program, containing both operator-controlled data measurement and typewriter dialogue between a computer program and an operator, is sufficiently illustrative of interactions that can occur so that the data on such a program are felt to be of help to system planners.

Caplan, S. H. Guidelines for reducing human errors in the use of coded information. Proceedings of the Human Factors Society, 19th Annual Meeting, Dallas, Texas, 1975.

This paper presents code design and display guidelines intended to make it difficult to generate a code-related error and easy to detect errors that still occur. Principles governing immediate memory and rules for making erroneous codes easily recognizable combine to form guidelines for code design. Design factors include various dimensions of code configuration length, the kind of characters, their location and grouping. These guidelines minimize the common errors of substitution, transposition, omission, and addition of characters. Besides the code itself, errors are also affected by the way the code is displayed. To further enhance reliability, additional guidelines are included for the size, style, and contrast of characters. A reliable code system requires a structure which is compatible with human recognition and short-term memory capabilities. These abilities have been extensively explored in the experimental psychology literature. The particular studies used as a basis for the code guidelines in this paper are those where recall follows perception by only a few seconds and no intervening information is processed in the interim. These experimental conditions correspond to usual transactions in which transcription or keypunching closely follows visual perception of the code.

Carbonell, J. R. On man-computer interaction: A model and some related issues. IEEE Transactions on Systems Science and Cybernetics 1968, SSC-5 (1), 16-26.

A survey of the literature related to man-computer interaction reveals the many aspects of this problem, which appears to be in the crossroads among such diverse fields as computer languages, computer systems operational characteristics, control theory, decision theory, information theory, applied psychology, computer display and interface engineering, etc. In this paper we have chosen to present the on-line interaction from an information and decision point of view. After a brief discussion of classes of on-line situations and tasks, we propose an information-processing model of the case in which a human operator is engaged on-line in the solution of a problem like debugging a program, testing a model in a scientific application, or performing a library search. In this model the human operator is considered to seek to maximize overall cost. This cost is obtained by adding the operational cost of both man and computer to a remnant terminal cost originated by the remaining uncertainty. This analysis, performed for each of a set of possible alternatives for action, may lead the man to select and execute one of them, to terminate the process, or to reevaluate the possible alternatives and/or hypotheses in a search for new ones. Some practical applications in terms of response time and other characteristics of a computer utility are discussed, as well as some theoretical implications from an informational point of view.

Carbonell, J. R., Elkind, J. I., and Nickerson, R. S. On the psychological importance of time in a time sharing system. Human Factors, 1968, 10, 135-142.

One of the most important problems in the design and/or operation of a computer utility is to obtain dynamical characteristics that are acceptable and convenient to the on-line user. This paper is concerned with the problems of access to the computer utility, response time and its effect upon conversational use of the computer, and the effects of load on the system. Primary attention is placed upon response time; rather than a single measure, a set of response times should be measured in a given computer utility, in correspondence to the different types of operations requested. It is assumed that the psychological value of short response time stems from a subjective cost measure of the user's own time, largely influenced by the value of concurrent tasks being postponed. A measure of cost (to the individual and/or his organization) of the time-on-line required to perform a task might thus be derived. More subtle is the problem of the user's acceptability of given response times. This acceptability is a function of the service requested (e.g., length of computation), and variability with respect to expectations due both to uncertainty in the user's estimation and to variations in the response time originated by variable loads on the system. An effort should be made by computer-utility designers to include dynamic characteristics (such as prediction of loads and their effects) among their design specifications.

Chapanis, A. I. Interactive human communication. Scientific American, March, 1975, 36-42.

A series of experiments is described in which two members of a problem-solving team are each given partial problem information. One of them, the "seeker", is assigned a particular task to perform, for which he requires information possessed by the other, the "source". The roles of these subjects are intended to correspond loosely to those of computer system user and computer system, respectively. The subjects are allowed to communicate through various media (voice, video, handwriting, typewritting, and various combinations), and the effects, both on problem-solving effectiveness and on the nature of the conversation, are observed. Conversations, while effective, were found to be extremely ungrammatical by formal english grammar standards. The presence or absence of voice communication as one of the allowed media was the most important experimental variable. Experimental conditions involving voice communication had more and shorter messages, more total words exchanged, greater message redundancy, greater communication rates and faster problem solution than other conditions.

Chu, Y. and Rouse, W. B. Optimal adaptive allocation of decision making responsibility between human and computer in multi-task situations. Paper presented at the International Conference on Cybernetics and Society, Washington, D. C., September 19-21, 1977.

It is suggested that the computer serve as a backup decision maker in multi-task situations, accepting responsibility when workload becomes excessive and relinquishing responsibility when workload becomes acceptable. A queueing theory formulation of multi-task decision making is used to develop a procedure for determining when the computer should be assigned decision making responsibility The procedure is illustrated by application to a computer-aided flight management situation.

Clapp, L. C. Man-computer interaction and context programming. Newton, Massachusetts: Computer Research Corporation, Report No. R102-6, July, 1970.

The report is concerned with the communication between man and the computer systems he uses for problem solving and management planning. To bridge the gap between problem solving needs and the ability of problem solvers to write their own programs, the trend has been to create pre-packaged programs which can solve a class of problems once the pertinent data has been supplied. One impediment toward the development of better problem solving tools which will operate in conjunction with on-time computer systems is a methodology for structuring the dialogue between the problem solver and his machine. A series of generalized dialogue handling routines was programmed for a time-sharing system operating on a Scientific Data Systems computer (SDS-940). The general set of routines is called the Command Package. The Command Package is then used in several different applications areas drawn from mathematics, engineering and general modeling and simulation.

Coffey, J. L. A comparison of vertical and horizontal arrangements of alpha-numeric material-experiment 1. Human Factors, 1961, 3, 93-98.

The objective of this study was to determine the relative effectiveness of visual displays containing alpha-numeric material displayed in vertical and horizontal arrangements. Variables included in the experimental design were: types of arrangement of display material, density of material, composition of material, and operator tasks. The major finding in the study was the non-significance of the arrangement variable. It was found that, for all practical purposes, the differential effects of vertical and horizontal arrangement of alpha-numeric materials on operator performance are negligible.

Collins, A. M. and Quillian, M. R. How to make a language user. In E. Tulving and W. Donaldson (Eds.) Organization of Memory, New York: Academic Press, 1972, 310-349.

This paper discusses how some of the major pieces of a language user fit together. The framework provided describes the human language user as viewed from the perspective of a computer. Two major sections are included in the paper, one about the structure of semantic memory and one about processing on that structure. For the structure, the nature of concepts and their relation to words and images, the kind of semantic information people learn and do not learn, and the kinds of inference-bearing relations that form the basis for the organization of semantic memory are discussed. With regard to processing, the semantic search during comprehension and retrieval, the tacit processing which this search implies, the pervasiveness of identifying similar concepts with each other in language processing, the decision rules that are applied to the results of a semantic search in order to decide whether two similar concepts can be identified, the role imagery plays in language processing, and the way people induce what properties to store with what concepts are discussed.

Cornog, D. Y. Human factors engineering in the postal service. Rockville, Maryland: U.S. Postal Service, Research and Development Department, Report No. 5HPD02-2, December, 1976.

The work done in solving human factors problems in postal operations and in the development of postal systems and equipment is presented in a chronologically arranged, annotated bibliography of Postal Service Human Factors Program reports, documents and related publications.

Cornog, J. R. and Craig, J. C. Keyboards and coding systems under consideration for use in the sorting of U.S. mail. Paper presented at the Sixth Annual Symposium of the Professional Group on Human Factors in Electronics, the Institute of Electrical and Electronic Engineers, Boston, Massachusetts, May 6, 1965.

In addition to a general discussion of Post Office human factors problems, specific comments cover the memorized numerical codes, the extraction codes (S-4, S-1 modified, and PAT), the unmemorized numerical codes (ZIP) and the several keyboards (Burroughs, Levy, FMC, and the Sack Sorter keyboards).

Crawford, A. M. Interactive computer graphics for simulation displays. Proceedings of the Human Factors Society, 21st Annual Meeting, San Francisco, California, 1977.

Interactive computer graphics were discussed within the context of recent research trends which represents a consolidation of simulation and learning technologies. Research that has utilized graphics for training was described and discussed in an attempt to assess the usefulness of the technology across a wide variety of applications.

Crooks, W. H., Artof, M., Weltman, G., and Freedy, A. Man/machine interaction in adaptive computer aided control: Analysis of automated control allocation. Woodland Hills, California, Perceptronics, Report No. PATR-1008-74-12/30, December, 1974.

Control allocation between the human operator and an intelligent control element is becoming an important part of advanced Navy systems, which place increasing emphasis on decision making as compared with manual control. The present research focuses on human factors criteria for the man/machine interactions in such shared decision and control systems. The research effort includes evaluations of task allocation methods, information feedback, decision risks, and operator indoctrination. This report presents the results of a series of experimental investigations of adaptive computer-aided control and task allocation.

Davis, R. M. Man-machine communication. Annual Review of Information Science and Technology, 1965, 221-254.

This is the first annual review of the field of man-machine communication. Accordingly, it has no prior context in which to frame itself. To achieve cohesiveness, it has been necessary to cite work of earlier years when no 1965 literature was found as illustrative of a particular topic being addressed. The review is selective in its references. Of some 210 documents that were scanned, only aproximately 50% are cited. The criteria for selection were varied and were rigorously followed only within the limitations of human error. Those documents cited either (1) contained excellent descriptions of particular applications, equipment or problem areas; (2) provided comprehensive coverage of a particular topical area; (3) advanced a particular method of approach or concept to which attention needed to be drawn; or (4) themselves highlighted a point the reviewer wished to make. Foreign literature was surveyed but little was found that met the selection criteria. Equipment and programming languages were intentionally neglected because of their inclusion in other areas of this Annual Review.

Durding, B. M., Becker, C. A., and Gould, J. D. Data organization. Human Factors, 1977, 19, 1-14.

Three experiments investigated how people organize data. Subjects were given sets of 15-20 words and asked to organize them on paper. Each word set has a pre-defined organization (hierarchy, network, lists, table) based on the semantic relations among the words. Experiment 1 showed that college students have all these organizational structures available for use. They organized most word sets on the basis of the semantic relations inherent in them. Whereas most subjects used "appropriate" organizations (those that most easily preserved the relations), a few subjects organized nearly all word sets into lists. Experiment 2 showed that subjects can efficiently fit word sets into "skeletons" that were explicitly designed to maintain all the semantic relations among the words. Experiment 3 showed that subjects have difficulty in preserving the relations among the words when they were required to organize them into inappropriate structures. These results are evaluated relative to the use of computer-based information retrieval systems.

Edwards, E. and Lees, F. P. The influence of the process characteristics on the role of the human operator in process control. Applied Ergonomics, 1974, 5 (1), 21-25.

Rational design of a process control system using an on-line computer requires a definition of the total control task and an allocation of function between the human operator and the machine. Both the nature of the total task and its subdivision depend very much on the process characteristics, which vary widely between different processes. The functions normally performed by a process control computer are described and those consequently left to the operator are defined. The wide variety of the operator's functions and the implications of this for studies of the operator's performance and for the design of the man-machine interface are emphasized.

Eisle, J. E., Williges, R. C., and Roscoe, S. N. The isolation of minimum sets of visual image cues sufficient for spatial orientation during aircraft landing approaches. Savoy, Illinois: University of Illinois at Urbana-Champaign, Aviation Research Laboratory, Technical Report, ARL-76-16/ONR-76-3, November, 1976.

An experimental investigation of synthetic imaging displays was directed toward the isolation of minimum sets of visual cues sufficient for spatial orientation in ground-referenced aircraft landing approaches. Thirty-two flight instructors viewed static computer-generated airport scenes TV-projected onto a large screen viewed from the cockpit of a twin-engine general aviation trainer. Judgments of lateral and vertical deviations from a four-degree approach to landing aim point in the display were made to 32 combinations of four contact analog cues: runway outline, runway touchdown zone, runway centerline, and ground plane texture; and one guidance cue: glidepath-localizer symbol. Each resulting display was responded to once or more from each of 27 different flight position and attitude viewpoints by each of eight subjects in different serial orders. Dependent measures were response choice and response latency. The most accurate glidepath and course deviation judgments were made when the guidance cue glidepath was in the set. When only contact analog cues were present the best judgments of spatial orientation consistently were made when the runway outline was present at far and medium ranges from touchdown and when the runway centerline was present at near range.

Engel, S. E. and Granda, R. E. Guidelines for man/display interfaces. Poughkeepsie, New York: International Business Machines, Report No. TR 00.2720, December, 1975.

This report documents a set of human factors guidelines relating to the interface between a user of an interactive computing system and a display terminal connected to the system. Though intended primarily for the use of developers of software for an interactive system, many of the guidelines should be of interest to hardware developers. Areas covered include display frame layout, frame content, command languages, error prevention and recovery, response times, and behavioral principles.

Enstrom, K. D. Real time adaptive modeling of the human controller with application to man-computer interaction. Urbana-Champaign, Illincis: University of Illinois at Urbana-Champaign, Coordinated Science Laboratory, Report No. R-715. UILU-ENG-76-2203, January, 1976.

When a human and computer are joined forming a human-computer system, the two decision-makers must work together if the human's workload is to be reduced and overall system performance maintained or improved. Independent actions by each decision maker could prove to be counterproductive. This thesis proposes that cooperation between decision makers can be fostered by using the computer to monitor the actions of the human. The human can act freely, and the computer will use decision policies that do not conflict with the human's current actions, but adapt to them.

Enstrom, K. D. and Rouse, W. B. Real-time determination of how a human has allocated his attention between control and monitoring tasks. IEEE Transactions on Systems, Man, and Cybernetics, 1977, SMC-7, 3, 153-161.

A computer algorithm employing fading-memory system identification and linear discriminant analysis is proposed for real-time detection of human shifts of attention in a control and monitoring situation. Experimental results are presented that validate the usefulness of the method. Application of the method to computer-aided decision-making in multitask situations is discussed.

Evans, R. C. and Miller, L. A. STARCAT, a system to analyze interactive CMS performance. Yorktown Heights, New York, IBM Thomas J. Watson Research Center, Report No. RC 7072 (# 30314), April, 1978.

This paper describes a software system named STARCAT - for STream Analysis of Responses by CATegory. The system analyzes sequences of user command strings that have been captured in a special timestamped CMS console file: user response times, URTs, and system response times. SRTs, are associated with each string; strings are assigned - by command name, environment, or experimenter-chosen groupings - into categories; and category statistics are reported for one, two, and three-string subsequences. STARCAT provides a new tool, valuable to various interface and system design studies, for the quantitative analysis of interactive terminal performance.

Fetter, R. B. Man-computer interaction in a decision-making environment. New Haven, Connecticut: Yale University, Department of Administrative Sciences, Annual Report No. 1, February 1, 1970 - Janury 31, 1971.

An experiment was formulated, conducted, and results reported involving video and teletype consoles in an information retrieval environment. In conjunctior with the development of an information system, a capability to simulate a variety of problem solving environments and automatically evaluate results was designed and programmed. This included the ability to give users on-line feedback of their relative effectiveness. Basic information relevant to further research was gathered, including: a bibliography of research in man-computer interaction; and a file of information on available computer consoles.

Flanagan, J. L. Computers that talk and lister: man-machine communication by voice. Proceedings of the IEEE, April, 1976, 64 (4), 405-415.

Computer techniques now emerging in the laboratory promise new capabilities for voice communication between man and machine. Three modes of interaction are of special interest: computer voice readout of stored information, automatic verification of a caller's identity by means of his voice signal, and automatic recognition of spoken commands. Applications extend to: voice-directed installation of telephone equipment, authentication by voice of a credit customer or of an individual requesting readout of privileged information, and voice-controlled services such as repertory dialing or automatic booking of travel reservations.

Fleishman, E. A. Performance assessment based on an empirically derived task taxonomy. Human Factors, 1967, 9, 349-366.

This report reviews and discusses a number of the methodological questions relating to the application of an experimental correlational approach to the problem of assessing complex performance. The basic point of departure is the specification of the requirements for a task taxonomy and an analysis of the value of factor analytic investigations in combination with experimental methods in providing the frame-work for such a taxonomy. The way in which this approach has been applied in the past and the expected benefits of its successful implementation are discussed. It is concluded that experimental - correlational studies offer considerable promise in attacking complex performance but that a more extensive research program is needed. The general outlines of such a program is described.

Foley, J. D. The human factors - computer graphics interface, Washington, D.C.: The George Washington University, Department of Electrical Engineering and Computer Science, June, 1978.

Most Interactive Computer Graphics Applications (ICGA) in use today have been developed with absolutely no help from human factors specialists. This situation is frustrating to all of us who recognize that good human engineering can be central to the success of an appliction. The cause of this dilemma is examined, and several remedies are prescribed. The process of designing an ICGA is described to illustrate the role of human factors engineering at each step of the design process, and to suggest a conceptual framework within which current human factors knowledge might be structured and future research might be performed.

Foley, J. D. and Wallace, V. L. The art of natural graphic man-machine conversation. Proceedings of the IEEE, 62 (4), April, 1974, 462-471.

The design of interactive graphic systems whose aim is good symbiosis between man and machine involves numerous factors. Many of those factors can be judged from the perspective of natural spoken conversation between two people. Guiding rules and principles for design of such systems are presented as a framework for a survey of design techniques for man-machine conversation. Attention is especially focused on ideas of action syntax structuring, logical equivalences among action devices, and avoidance of psychological blocks to communication.

Frederico, P. A. Computer-based management information systems: Is there really an "information glut?" Proceedings of the Human Factors Society, 19th Annual Meeting, Dallas, Texas, 1975.

Some salient issues are identified and discussed concerning computer-based managemnt information and decision systems and managerial behavior. The literature in this area is very inconsistent and uncertain with respect to the alleged impact of these automated systems upon managerial information processing and decision making. This underscores the almost complete absence of empirical data regarding the implications of these systems for managerial behavior. Research should be initiated to explore empirically what the impacts of computerized information systems are for management.

Freund, R. J. and Hartley, H. O. A procedure for automatic data editing. American Statistical Association Journal, 1967, 62 (318), 341-352.

Since raw data from sample surveys and experiments often contain errors, attempts are usually made to edit data to make them more useful for analytic purposes. Increasing portions of this editing are now being accomplished by high speed computers. The great variety of such procedures reflects the conflicting desires of providing editing procedures which recognize peculiarities of particular data sets and yet are easily programmed and implemented. This paper proposes a scheme which is hoped to be suitable for a large variety of sample and survey data and yet be relatively easy to implement once a general program has been written.

Galitz, W. O. and Laska, T. J. Computer system peripherals and the operator. Computer Design, August, 1969, 12, 52-56.

Little effort has been directed toward increasing the understanding of the role of the (computer) operator in the system. Observing, measuring and understanding his behavior is essential if systems engineered and designed for humans are to be developed. Highlights of a study of the computer operator's relationship to peripheral devices is presented here.

Gallenson, L. An approach to providing a user interface for military computer-aided-instruction in 1980. Marina del Rey, California: Marina del Rey Information Sciences Institute, Report No. IS/RR-75-43, November, 1975.

A recent needs study determined that most of the terminal requirements for military CAI applications can be satisfied with mainstream commercial terminals. Additional development, however, is likely to be required to satisfy two of the capabilities (limited graphics and prerecorded visuals). The expected architecture of commercial terminals will make it easy to modify and customize them to meet all the identified CAI needs. The military community is also expected to use computer networks to satisfy an appreciable portion of its requirements. Commercial terminals and available computer networks provide the basis for an effective and economical user interface to military CAI systems.

Garvin, P. L. Language and machines. International Science and Technology, May, 1967, 63-98.

Natural language research attempts to simplify man's problems of communicating with machines or through machines via automatic translation. Query languages resemble natural language and enable computers to compose answers to a limited variety of questions. But synonomy of words is frequently conditional, so computer programs must recognize semantic ambiguities and syntax as well as have large dictionaries. The automatic translation possible now is really machine-aided. There is strong disagreement whether development of a theory of language should precede the engineering of a reliable methodology for machine translation, for successful, if not perfect, data processing can be based on empirical knowledge.

Gould, J. D. Visual factors in the design of computer-controlled CRT displays. Human Factors, 1968, 10, 359-376.

This paper is concerned with the important visual variables that determine image quality on computer-controlled CRT displays. A strategy is developed that leads to general conclusions about each variable even though most of these variables interact. For each variable considered, the recommended range of values is determined on the basis of experimental evidence and is compared with the values presently used on displays. Where discrepancies between these two exist, alternative solutions are mentioned. Conclusions are (i) presently used values of display luminance, chromaticity (color), and resolution are adequate; (ii) several displays flicker; (iii) characters are large enough but may be marginal in terms of number of elements; (iv) luminance contrast is not adequate.

Gould, J. D. Some psychological evidence on how people debug computer programs. International Journal of Man-Machine Studies, 1975, 7, 151-182.

Ten experienced programmers were each given the same 12 FORTRAN listings to debug. Each listing contained a non-syntactic error in one line. Median debug times (7 min), number of bugs not found (11% of the listing), and number of incorrect assertions about the location of the bug (less than one per listing) all replicated earlier results (Gould & Drongowski, 1974). Although subjects were given the opportunity to use the interactive debugging facilities of an on-line computer, they rarely did so. Bugs in assignment statements were about three times as hard to detect as array or interaction bugs. Debugging was about three times as efficient on programs subjects had debugged previously (although with a different bug). A number of basic concepts and a gross theory of debugging is described.

Gould, J. D. and Ascher, R. N. Use of an IQF-like query language by non-programmers. Yorktown Heights, New York: IBM Thomas J. Watson Research Center, Behavioral Sciences Group, Computer Sciences Department, Report No. RC-5279 (#23163), February, 1975.

This exploratory experiment attempts to examine separately the formulation, planning, and coding of queries. College students and file clerks required about ten hours to learn a query language which was somewhat similar to IBM's IQF query language, but contained more function. They were then given 15 test problems that varied in complexity and how well they were expressed. Subjects were required to formulate, then to plan (writing each in their own words), and finally to code each problem. Results provide some suggestions about which problem variables affected which stages in writing queries. For example, whether or not a problem was well expressed seemed to affect problem formulation time, but had no affect upon problem planning or problem coding times. Specific language constructions (additions to IQF), such as contextual referencing and a new method to handle limited disjunctive problems, were shown to be useful. The types of coding errors that subjects made were identified and discussed.

Gould, J. D. and Boies, S. J. Writing, dictating, and speaking letters. Yorktown Heights, New York: IBM Thomas J. Watson Research Center, Report No. RC-6683 (#28698), August, 1977.

This research aims at understanding psychological processes in document composition, particularly in dictation, through measurements of authors' actual performance and their perception of their performance. It is commonly assumed that dictation requires a long time to learn but authors eventually become much faster than with writing. Evidence presented here suggests this is not true, although authors believe this to be the case about their own performance. Novice dictators learned in a few hours to dictate with the same speed and quality as they wrote; expert dictators were only 0-25% faster than novices, depending upon the complexity of the letters.

Gould, J. D. and Drongowski, P. An exploratory study of computer program debugging. Human Factors, 1974, 16, 258-277.

This experiment represents a new approach to the study of the psychology of programming, and demonstrates the feasibility of studying an isolated part of the programming process in the laboratory. Thirty experienced FORTRAN programmers debugged 12 one-page FORTRAN listings, each of which was syntactically correct but contained one non-syntactic error (bug). Three classes of bugs (Array bugs, Iteration bugs, and bugs in Assignment Statements) in each of four different programs were debugged. The programmers were divided into five groups, based upon the information, or debugging "aids", given them. Key results were that debug times were short (median = 6 min). The aids groups did not debug faster than the control group; their debugging strategies based upon the information available to them. The results suggest that programmers often identify the intended state of a program before they find the bug. Assignment bugs were more difficult to find than Array and Iteration bugs, probably because the latter could be detected from a high-level understanding of the programming language itself. Debugging was at least twice as efficient the second time programmers debugged a program (though with a different bug in it). A simple hierarchical description of debugging was suggested, and some possible "principles" of debugging were identified.

Gould, J. D., Lewis, C., and Becker, C. A. Writing and following procedural, descriptive and restricted syntax language instructions. Yorktown Heights, New York: IBM Thomas J. Watson Research Center, Report No. RC-5943(#25753), April, 1976.

Two exploratory experiments compared the way people (with no experience in the use of computing systems) write and carry out natural language procedures, natural language descriptions, and instructions expressed in an artificial restricted syntax language. The results suggest that there is no single 'natural' way that people write simple plans and instructions. Speed and accuracy of writing were about the same for all three approaches, although the linguistic characteristics differed greatly from approach to approach. While subjects were tolerant of ambiguity both in writing and in carrying out instructions, they often voluntarily employed restricted-syntax notation in their writing after being exposed to the notation. Subjects' accuracy in following detailed instructions was no greater than that in writing those instructions.

Grignetti, M. C. and Miller, D. C. Information processing models and computer aids for human performance, Task 2. Models of human-computer interaction. Cambridge, Massachusetts: Bolt, Beranek, and Newman, Inc., Report No. BBN-2186, June, 1971.

Experiments were conducted to explore methods of motivating time-sharing users to adopt behavior patterns that improve overall system performance. It was found that while it is indeed possible for a time-sharing system to provide incentives to users that will affect their choices between alternatives methods of accomplishing a given task, the extent of this effect is not entirely predictable. Also designed and implemented was a measuring system for the SDS-940 time-sharing computer system. This measuring system yielded data that were useful in increasing an understanding of the dynamic behavior of programs in a time-sharing system and, more specifically, in improving overall system performance.

Grignetti, M. C., Miller, D. C., Nickerson, R. S., and Pew, R. W. Information processing models and computer aids for human performance, Task 2. Human-computer interaction models. Cambridge, Massachusetts: Bolt, Beranek, and Newman, Inc. Report No. BBN-2190, June, 1971.

A measuring system was implemented to obtain the statistical parameters necessary to specify a queueing theory model of the dynamic behavior of a state-of-the-art time-shared computer system, and present results on the statistics of usage of one such computer system. A methodology is presented for the performance of experiments involving human users and for the interpretation of their results. It is expected that these results will yield predictive models for the overall efficiency of the 'users-computer system' under various circumstances.

Grimes, F. M. and Otto, R. E. A study of some software parameters in time-sharing systems. Unpublished master's thesis, Naval Postgraduate School, Monterey, California, 1965.

A review is made of some existing time-sharing computer systems and an exploration of various software characteristics is conducted. This investigation is conducted using a computer program with which a typical time-sharing system can be simulated. The basic system parameters examined are: (1) the method of determining the quantum time for each user per response cycle, (2) the length of the desired response cycle, (3) the number of remote stations permitted and (4) the maximum number of users permitted in the queue at one time. The results of these simulation runs are presented. The effects of the various parameters upon the average response cycle time, the average number in the queue awaiting service, the average length of time a user is in the queue and the computational efficiency plus other characteristics of the system are discussed.

Grossberg, M., Wiesen, R. A., and Yntema, D. B. An experiment on problem solving with delayed computer responses. IEEE Transactions on Systems, Man, and Cybernetics, 1976, 6 (3), 219-222.

Four subjects solved problems on line with the Lincoln Laboratory Reckoner. Controlled delays were interposed between output commands and the resulting outputs, which were via typewriter, cathode-ray tube (CRT), or line printer; other commands were executed promptly and without reply. The mean delay was 1, 4, 16, or 64 seconds, with individual delays varying widely and unpredictably about the mean. Data on nine problems per delay per subject showed that at longer delays the rate of which commands were given decreased, especially the rate of output commands, and that the problems were solved with fewer outputs in about the same time. With two subjects, there was a marked effect of delay on the relative frequency of use of the three output devices.

Harris, L. R. Natural language data base query: Using the data base itself as the definition of world knowledge and as an extension of the dictionary. Hanover, New Hampshire: Dartmouth College, Department of Mathematics, Report No. TR 77-2, February, 1977.

This paper raises two issues that heretofore have not been dealt with in any previous natural language data base query system. These issues arise because of the everpresent need for world knowledge in the understanding of English, and also because of the particular way in which information is stored in a data base. The solutions to these problems described in this paper require only existing state of the art data base technology.

Heafner, J. F. A methodology for selecting and refining man-computer languages to improve users' performance. Marina del Rey, California: Marina del Rey Information Sciences Institute, Report No. ISI/RR-74-21, September, 1974.

This report describes a methodology (supported by a software package) to model, measure, analyze, and evaluate users' performance in a message communication system environment. The theses of the report are: 1. that models of users and services can be accurately used as predictors in selecting a language form, for an application, which will result in high users' performance, and 2. that such a language form is only an approximation (in terms of yielding optimal user's performance) due to within variances of user and service-classes, hence individual, on-line regulation of language constructs is necessary to further improve performance. This report develops appropriate models and algorithms, and states hypotheses relating the interactive effects of users, services, language forms, and other variables important in man-machine discourse. An experiment design is presented, which tests the major hypotheses.

Hitt, H. D., Schutz, H. G., Christner, C. A., Ray, H. W., and Coffey, J. L. Development of design criteria for intelligence display formats. Human Factors, 1961, 3, 86-92.

A broad research program to develop design criteria for intelligence display formats is outlined and the general findings of the program are discussed. Five specific areas of investigation are selected for study: a comparison of vertical and horizontal arrangements of alpha-numeric material, an evaluation of formats for trend displays, an evaluation of methods for presentation of graphic multiple trends, an evaluation of five abstract coding methods, and an evaluation of the effect of selected combinations of target and background coding on map reading performance. The five succeeding articles treat the five areas of investigation in detail.

Jordan, N. Motivational problems in human-computer operations. Human Factors, 1962, 4, 171-175.

In designing machines and man-machine systems, Human Factors Engineering has generally concentrated upon seeking solutions to physiological problems to enable the human operator to function efficiently. It has, however, neglected the psychological problems, particularly the problems of motivation. This was not too critical as long as machines were "primitive." With the advent of automation and complex man-machine systems this neglect may have most undesirable effects. An attempt is made to identify the necessary conditions which make a task, per se, motivating. Examples are cited from some new systems where some of these necessary conditions are lacking and the effect of this lack upon the operator is indicated.

Kane, D. F., Jr. Observational research in user-computer interaction. Berkeley, California: Lawrence Berkeley Laboratory and Energy Research and Development Administration, Report No. CONF-7510100-1, October, 1975.

This paper is primarily concerned with methodology in this field of research. First, the nature of user-computer interaction in information systems is described, and viable types of research are suggested. Then the observational methodology of heuristic development is presented, and the value both of teamwork and of evolutionary development is discussed. Next, the management context at the Lawrence Berkeley Laboratory is described. Finally, some measures of success are discussed, as exemplified by the expanding use of the Budget Management System in the Lawrence Berkeley Laboratory Management Information System.

Kelley, C. R. Manual and automatic control. New York: Wiley, 1968.

This book presents a theory of the human control process in man/machine systems. Also, manual control system applications are discussed in a technically-oriented approach. Implications of the control theory for automatic control are examined. Chapter titles include the following: The control process, the control system, the control system hierarchy, the human operator: consciousness and planning in the control process, the human operator: motor performance, adaptation and optimization by the human operator, information requirements and receptor channels, status displays, displays and control augmentation: command displays, historical and predictor displays, techniques of adaptive manual control, controls, engineering models of the human operator, predictive and review models of the human operator, the Ziebolz automatic controller, and the role of man in automatic control processes.

Kelly, M. J. Studies in interactive communication: Limited vocabulary natural language dialogue. Baltimore, Maryland: Johns Hopkins University, Department of Psychology, Report No. TR-3, August, 1975.

The complexity and costs of interactive, natural-language computer systems could be reduced if the man-computer communication used only a limited subset of the English language. The purpose of this study was to test the hypothesis that people, although accustomed to unrestricted use of the language, can efficiently interact using a carefully chosen subset of a few hundred words. Two-person teams communicated through a computer-controlled teletypewriter system to cooperatively solve real-world problems. They were permitted to use only words on predetermined lists of 300 words, of 500 words, or as a control condition, with no vocabulary restrictions. The teams solved a different problem on each of three successive days. Dependent measures were taken on four classes of variables: (1) time to solve the problem, (2) several measures of overt behavior, (3) several measures of verbal output, and (4) measures of errors made by subjects using the two restricted vocabularies. There were numerous significant effects of the Problems, the Job roles of subjects within the team, and the Problem X Job Role interaction. However, the more interesting main effect of Vocabulary Size was significant for only three of the 21 dependent measures. Furthermore, only four of the 105 interactions involving Vocabulary Size were statistically significant. This study presents strong evidence of the adaptability of the human communicator. Although sometimes exhibiting frustration with the small vocabularies, the subjects were, nonetheless, able to solve their problems about as successfully as did their counterparts in the unlimited vocabulary condition.

Kling, R. Who needs a person-centered computer technology? Madison, Wisconsin: University of Wisconsin, Department of Computer Sciences, Report No. WIS-CS-169-73, 1973.

Contemporary computer designers are largely machine centered and emphasize function and standards of elegance, efficiency and computing power. The side effects of systems may enhance or diminish the well being of various users. Recent studies of the human impacts of computing systems are described. Person centered standards that promote a sense of competence and autonomy are outlined. The coupling of flexible software with responsive organizations is suggested as a means of enhancing personal competence and self-esteem.

Knoop, P. A. Advanced instructional provisions and automated performance assessment. Human Factors, 1973, 15, 583-597.

An advanced simulation research system is being developed to support experiments oriented toward quantifying the effect on transfer of training of alternative training and simulation techniques. Included in the system is sophisticated training research software which automates most of the functions traditionally performed by flight simulator instructors or operators. Also under development are techniques for automatically assessing pilot proficiency in the simulator and in the operational aircraft. Recent feasibility studies in performance measurement resulted in identification of necessary flight variables for assessing proficiency on two undergraduate pilot training maneuvers; established alternative approaches to developing measurement techniques on a broader scale; applied existing technology to develop an in-flight data acquisition system for the T-37 aircraft; and raised (or, more correctly, reraised) issues regarding standardization in instruction and rating procedures.

Knoop, P. A. Man-computer symbiosis through interactive graphics: A survey and identification of critical research areas. Brooks AFB, Texas: Air Force Human Resources Laboratory, Report No. AFHRL-TR-77-10, April, 1977.

The major distinguishing feature of man-computer symbiosis is the capability of both man and computer to transceive relevant unrequested information. Using this derived definition, basic key requirements of a symbiotic system were projected. These included: (1) transceivers and memories, (2) graphics techniques, (3) a language, and (4) an attention-getting capability. A literature survey revealed that raster scan cathode ray tubes hold the greatest promise for use in symbiotic systems, but that a critical problem accompanies their use in that scan conversion methods are required. Existing methods are either too time consuming or too memory consuming. A promising technique was found for reducing the number of vectors comprising a scene. This technique would find its greatest utility in random scan systems, where its use may provide flicker-free displays. Little work has been performed in extending man's memory precision and recall capability. There are no methods with immediate utility for symbiotic systems for efficiently removing hidden lines and surfaces to effect a 3-D display. Finally, it was determined that the most promising solution to the language problem lies in the development of hybrid communication techniques using a combination of graphic languages and small scale voice input methods.

Kobrick, J. L. Effects of physical location of visual stimuli on intentional response time. Natick, Massachusetts: Army Research Institute of Environmental Medicine.

The effects of physical location of visual stimuli on the IRT were investigated. Sixteen subjects performed a simple manual response to flash stimuli located at 32 different positions in the visual field. The results indicated that IRTs were unaffected for most lower visual hemisphere locations. Significant decrements were only observed for locations higher than 30 degrees above the horizontal for lateral displacements greater than 55 degrees from center. No significant decrements were observed even at the periphery for locations along the horizontal line of sight.

Lenorovitz, D. R. and Ramsey, R. H. A dialogue simulation tool for use in the design of interactive computer systems. Proceedings of the Human Factors Society, 21st Annual Meeting, San Francisco, California, 1977.

A recurrent problem in designing interactive computer systems is the inability of system designers, users, and implementors to observe the system's external behavior until implementation has occurred. This, in turn, often results in failure to detect design deficiencies until a point when corrections are costly or impractical. A simulation tool is described which allows a systems designer to interactively specify, implement, demonstrate, evaluate, and iteratively modify an operational simulation of the proposed system's user-computer interface. The tool is intended for hands-on usage by an applications-oriented systems designer with little or no formal training in computer software programming. The capabilities and characteristics of the tool are described along with an economical and efficient approach to its design and implementation.

Levin, J. A. and Archbold, A. A. Working papers in dialogue modeling, Volume 1. Marina del Rey, California: Marina del Rey Information Sciences Institute, Report No. ISI/RR-77-55, January, 1977.

The five technical working papers that compose this document (which appears ir two volumes) were prepared as part of the Dialogue Modeling Project AT ISI. Though diverse in scope, all are related to the problem of creating a valid process model of human communication in dialogue. All are unpublished and all but one are in a form intended for internal use by the project team; however, they are of interest beyond the boundaries of the project and have implications for relatd work in modeling human communication. In Volume I both papers are on reference as a phenomenon in text. The first surveys reference identification and resolution methods in various existing natural language procesors. The other paper explores the broader problem of reference, focusng on text reference and propositional reference. It develops problems and proposals for defining these categories of reference phenomena and for detecting instances of them.

Levin, J. A. and Moore, J. A. Dialogue-games: Meta-communication structures for natural language interaction. Marina del Rey, California: Marina del Rey Information Sciences Institute, Report No. ISI/RR-77-53, January, 1977.

Our studies of naturally occurring human dialogue have led to the recognition of a new class of regularities which characterize important aspects of communication. People appear to interact regularly according to established patterns which span several turns in a dialogue and which recur frequently. These patterns appear to be organized around the goals which the dialogue serves for each participant. Many things which are said later in a dialogue can only be interpreted as pursuit of goals established earlier in the dialogue by goal-setting parts of these patterns. These patterns have been represented by a set of knowledge structures called Dialogue-games, capturing shared conventional knowledge that people have about communication and how it can be used to achieve goals. A Dialogue-game has Parameters, which represent those elements that vary across instances of a particular pattern. The Parameters identify the particular dialogue participants and the content topic. The states of the world which must be in effect for a particular Dialogue-game to be employed successfully are represented by Specifications of these Parameters. Finally, the expected sequence of intermediate states that occur during instances of a particular conventional pattern are represented by the Components of the Dialogue-game. This report describes a representation for several Dialogue-games, based on our analyses of different kinds of naturally occurring dialogue. A process model is described, showing Dialogue-game identification, pursuit, and termination as part of the comprehension of dialogue utterances. This Dialogue-game Model captures some of the important functional aspects of language, especially indirect uses to achieve implicit communication.

Licklider, J. C. R. Man-computer symbiosis. IRE Transactions on Human Factors in Electronics, March, 1960, HFE-1, 4-11.

Man-computer symbiosis is an expected development in cooperative interaction between men and electronic computers. It will involve very close coupling between the human and the electronic members of the partnership. The main aims are 1) to let computers facilitate formulative thinking as they now facilitate the solution of formulated problems, and 2) to enable men and computers to cooperate in making decisions and controlling complex situations without inflexible dependence on predetermined programs. In the anticipated symbiotic partnership, men will set the goals, formulate the hypotheses, determine the criteria, and perform the evaluations. Computing machines will do the routinizable work that must be done to prepare the way for insights and decisions in technical and scientific tinking. Preliminary analyses indicate that the symbiotic partnership will perform intellectual operations much more effectively than man alone can perform them. Prerequisites for the achievement of the effective, cooperative association include developments in computer time sharing, in memory components, in memory organization, in programming languages and in input and output equipment.

Licklider, J. C. R. Man-computer partnership. Science and Technology, May, 1965, 18-26.

Until recently, efforts to conserve the valuable time of an expensive computer precluded an interactive partnership between man and high-speed computing machine. But man excels in the heuristic phases of problem solving while the computer excels in executing explicit procedures. On the frontiers of research, heuristic and algorithmic information processing are not easily separated, but now a human problem solver can ask a computer to explore his hunches. Large computers are generally needed to handle problem-oriented languages, large files, and complex problems. The computer cost is shared among many users as the machine rapidly shares its available time. New kinds of displays and consoles enable man and computer to communicate by printing or writing or by drawing pictures and symbols. Special timesharing programs and dynamic displays are still costly. A whole new community of sophisticated users may produce results worthy of the expense.

Maddox, M. F., Burnette, J. T., and Gutmann, J. C. Font comparison for 5 x 7 dot matrix characters, Human Factors, 1977, 19, 89-94.

Two newly designed fonts and the Lincoln/Mitre font are compared for legibility using tachistoscopic presentation and forced identification. All three fonts were constructed with a matrix of 5 x 7 dots and were presented with a computer-generated display. The results were analyzed parametrically in terms of total identification errors and by conventional confusion matrices. The analysis showed significantly fewer errors with the font utilizing the largest number of dots per symbol than with either of the other two fonts. The confusion matrices revealed that the most severe confusions occur for different characters in different fonts.

Mann, W. C. Dialogue-based research in man-machine communication. Los Angeles, California: University of Southern California, Marina Del Rey Information Sciences Institute, Report No. ISI/RR-75-41, November, 1975.

This paper first surveys current knowledge of human communication from a point of view which seeks to find or develop knowledge that will be useful to computer system designers. The relevant scientific knowledge is found to be fragmentary and hard for designers to use. Next, the problem of complexity is explored. Building a useful knowledge of human communication is an extremely complex task. Controlling this complexity and its effects, without giving up usefulness, is seen as the central problem in designing a research approach. Finally, a new research methodology is presented. It contains some innovations that help control the complexity of the task, and others that make the results useful to designers. The methodology is unique in that it is based on case analysis rather than functional system design, the results are in the form of individual computer algorithms (much smaller than systems), and the algorithms are transferable into useful (nonresearch) systems.

Mann, W. C. Man-machine communication research. Los Angeles, California: University of Southern California, Marina Del Rey Information Sciences Institute, Report No. ISI/RR-77-57, February, 1977.

This is the final report of a multifaceted research and development effort in man-machine communications. The general goal of the program is to facilitate existing and future man-machine communication in areas of high military impact, including rapidly expanding use of on-line computing in communications and command and control. Highlights of the accomplishments of this research include: identification of major causes of man-machine communication difficulty for the computer-naive: discovery of major communication structures in human communication that have been left out of man-machine communication; creation of a process model that exhibits these structures in a form which can be imitated directly in creating new man-machine communications processes; creation of a new overview of how human communication functions in cooperative task-oriented activity; and assistance in ARPA policy formation or CAI equipment development.

Mann, W. C., Scragg, G., and Archbold, A. A. Working papers in dialogue modeling - Volume 2. Marina del Rey, California: Marina del Rey Information Sciences Institute, Report No. ISI/RR-77-56, January, 1977.

The five technical working papers that compose this document (which appears in two volumes) were prepared as part of the Dialogue Modeling Project at ISI. Though diverse in scope, all are related to the problem of creating a valid process model of human communication in dialogue. All are unpublished and all but one are in a form intended for internal use by the project team; however, they are of interest beyond the boundaries of the project and have implications for related work in modeling human communication. In Volume 2 the first paper concerns study methodology. It raises some of the following issues: how to choose between system-building and process-building, why studying cases is preferable to implementing general language-use functions as programs, how to control ad-hocness of results, why it is important to orient toward communication phenomena (in contrast to form phenomena) when studying natural language. The second is a design paper on the Match process of the Dialogue Model System, exploring methods for making it efficient and selective in its actions. The third concerns the structure of persuasion dialogues, in particular how justification of actions appears in argumentation.

Martin, J. Design of man-computer dialogues. Englewood Cliffs, New Jersey: Prentice-Hall, 1973.

This book is based on a course given at the IBM Systems Research Institute. It deals with many aspects of human-computer transactions. Section headings include the following: alphanumeric dialogues, dialogues with sound and graphics, psychological considerations operators without training, and implementation considerations.

Martin, T. H., Stanford, M. C., Carlson, P. R., and Mann, W. C. A policy assessment of priorities and functional needs for the military computer-assisted instruction terminal. Marina del Rey, California: Marina del Rey Information Sciences Institute, Report No. ISI/RR-75-44, December, 1975.

A policy study was conducted in four rounds to assess the anticipated payoff of an investment by ARPA in the development of new terminals for use by the military in computer-assisted and computer-managed instruction. Members of the panel of experts (11 civilian, 9 military) proposed features, rated them, and reacted to the resulting ratings. Of the 24 features, those rated as most needed were seen by these experts as likely to be in commercial production five to ten years from now in a form usable by the military. Experts generally agreed that investments in innovative pedogogical software and in innovative coursewriting are likely to have a greater payoff than an investment in terminal development. Of 14 software features, those rated as most needed are ones for particularizing instruction online to the course-related needs of individual students. The report is a thorough description of the conduct of the study.

Mathieu, R. D. Man-computer interaction conference. London, England: Office of Naval Research, Report No. ONRL-C-11-71, July, 1971 .

Within the past few years great strides have been made in computer technology, in particular in remote-terminal time-sharing facilities and computer languages. For the first time the computer and its tremendous powers have been brought within the reach of such people as teachers, doctors, managers, architects, designers, etc. This report describes the procedures of the Man-Computer Interaction Conference, which was held at the National Physical Laboratory, Teddington, UK on September 2-4, 1970. Emphasis was placed on the computer use and computer applications.

McCommons, P. B., Cook, T. C., and Glumm, M. M. A comparative study of single-versus double-sequence data-entry methods for use with the SB-3614/TT switchboard. Aberdeen Proving Ground, Maryland: Human Engineering Laboratory, Report No. HEL-TM-22-75, September, 1975.

Three methods of programming trunk-terminal assignments into the electrically alterable non-volatile memory (EVANVM) of the SB-3614/TT switchboard were compared. One was the double-sequence method recently proposed by the SB-3614/TT contractor (GTE Sylvania, Needham Height, MA). The other two were single-sequence methods developed by the authors. The two single-sequence methods used identical data entry procedures: but with one, visual feedback was supplied to the test subjects (Ss) as an alphanumeric display. Results of this study showed that both single-sequence method were superior to the double-sequence method. In the Ss could program faster and made fewer errors. Of the two single-sequence methods, the one employing visual feedback enhanced Ss performance, but, overall, this enhancement was not statistically significant.

Miller, L. A. and Thomas, J. C., Jr. Behavioral issues in the use of interactive systems. Yorktown Heights, New York: IBM Thomas J. Watson Research Center, Report No. RC-6326 (#27179), December, 1976.

This paper identifies behavioral issues related to the use of interactive computers primarily by persons who are not computer professionals, so-called 'general users.' This is not an exhaustive literature survey but instead provides: (1) a structure for discussing issues of interactive computing, and (2) the authors' best estimate of importance behavioral problems, with suggestions for solutions. The discussion is limited to this paper to general issues which do not take into account the user's particular task. The two major topics are System Characteristics (performance, facilities, and on-line information), and Interface Characteristics (dialogue style, displays and graphics, other input/output media).

Miller, R. B. Response time in man-computer conversational transactions. AFIPS Conference Proceedings, 1968, 33, 267-277.

The literature concerning man-computer transactions abounds in controversy about the limits of "system response time" to a user's command or inquiry at a terminal. Two major semantic issues prohibit resolving this controversy. One issue centers around the question of "Response time to what?" The implication is that different human purposes and actions will have different acceptable or useful response times. This paper attempts a rather exhaustive listing and definition of different classes of human action and purpose at terminals of various kinds. It will be shown that "two-second response" is not a universal requirement. The second semantic question is "What is a need or requirement?" In the present discussion, the reader is asked to accept the following definition: "A need or requirement is some demonstrably better alternative in a set of competing known alternatives that enable a human purpose or action to be implemented." This definition intentionally ignores the problem of value versus cost. It is not offered as a universally useful definition of "need." It does enable us to get into a systematic exposition of problems, alternatives and implications. A value-based definition, in contrast to the rational one given here, inevitably leads to a vicious regress that dead-ends only with the agreement that all that humans really need are food, water, and a place to sleep. Another point of view, compatible with the present one, is that need is equivalent to what is demanded and what can be made available; need, therefore, is a cultural and technical outcome.

Miller, R. B. Archetypes in man-computer problem solving. Ergonomics, 1969, 12 (4), 559-581.

Information systems applied to operational environments have meaning only in what they do for humans performing tasks, whether clerical, technical or managerial. Each person's job-position entails interaction with a limited set of categories of variable data. By 'limited' is meant less than several thousand, and more likely several hundred, categories. A category set associated with a collection of tasks performed by an individual or an organization may be called a category domain. This concept makes possible a practicable (in size) data base responsive to support human tasks in human (psychological) time. An analysis of human problem-solving tasks reveals the following gamut: simple inquiry and update, status inquiry, briefing, exception detection, diagnosis, planning/choosing, evaluating/optimizing, constructing (designing), and discovery. There is no compulsive ordering of these on a complexity scale. The information processing structure of each is examined: some common denominators among this set reveal five underlying archetypes of interaction. By making these archetypes explicit and consistent with concepts of domain, application disciplines and system design can move in parallel and generate a simple, well-defined language structure between system and human user.

Mills, R. G. Man-computer interaction-present and future. IEEE International Convention Record, 1966, 14, 196-198.

The potential of the large-scale computer system is greatly enhanced by the addition of man-machine interaction using appropriate terminal devices and languages. In fact, the man-machine coupling problem in its full breadth is the central issue in advancing interactive-computer technology. Some possible future directions are indicated.

Mills, R. G. Man-machine communication and problem solving. Annual Review of Information Science and Technology, 1967, 2, 223-254.

This chapter begins with a brief statement of the basic approach and the criteria used in selecting the material to be cited. A summary of the principal sources follows; this is followed by the main body of the review. The rather lengthy conclusion attempts to place the 1966 state of affairs in perspective. It is a reference frame and status summary, but also an implicit statement of the reviewer's viewpoint.

Minton, G. Inspection and correction error in data processing. American Statistical Association Journal, 1969, 64 (328), 1256-1275.

It is common practice to assume that inspectors of sample items and correctors of items in rejected work lots carry out their job without error and invariably classify defectives and nondefectives correctly. This assumption does not agree with experience in data processing activities, especially those requiring interpretation and judgment as well as clerical or machine skills. This paper emphasizes the error of classifying defectives as nondefectives(TypeII) made by inspectors called "verifiers" and by correctors to prepare data for machine readability. The following activities are included (1) verification of card punching, (2) proofreading of typed data, (3) verification of codes clerically assigned to written responses on questionnaires, (4) matching of codes assigned independently by three coders to the same item, and (5) proofreading of the output of special typing combined with coding and rounding figures for input to optical scanning.

Moore, J. A., Levin, J. A., and Mann, W. C., A goal-oriented model of natural language interaction. Marina del Rey, California: Marina del Rey Information Sciences Institute, Report No. ISI/RR-77-52, January, 1977.

This report summarizes a research program in modeling human communicative ability. The methodology involved selecting a single, naturally-occurring dealogue, instructng a human observer to extract certain aspects of the dialogue relating to its comprehension, and then using these aspects to guide the model building and verification activity. Behind the model is the development of an innovative theory of language, according to which people engage in language behavior in order to pursue their own goals. Dialogues communicate effectively because of a shared understanding of a collection of interrelated, cooperative goal structures, held and pursued by the language users. The recognition of this shared knowledge within the model contributed to an initial accounting of implicit communication. The report contains a detailed statement of the problems, a review of the state of related research, a description of the contributions of this research to linguistic theory and an explanation of the research methodology. It then describes the model in its current state of development and discusses a detailed simulation of it. Next the role of the observer in the research is explored with emphasis on the nature of his task.

Morfield, M. A., Wiesen, R. A., Grossberg, M., and Yntema, D. B. Initial experiments on the effects of system delay on on-line problem solving. Cambridge, Massachusetts: Massachusetts Institute of Technology, Lexington Lincoln Laboratory, Report No. TN-1969-5, June, 1969.

Three experiments explored the way in which delay in the response of the system affects the user's performance in solving problems with an on-line computing service. In each experiment there were four subjects under delay conditions of about 1 sec. to 100 sec. The on-line computing service was the Lincoln Reckoner. As expected, the average time the user required to complete a task increased as the response-delay increased, and the rate at which he demanded service declined as the delay increased. The relation of net completion time (time to complete the task, minus the time during which the user was waiting for a response) to response delay depended on the type of task. In the more realistic experiments, the net completion time increased with delay (suggesting that long delays are distracting). The number of outputs (i.e., displays or type-outs) per task was also considered. The main conclusion is that controlled experiments of this kind are feasible and can be used as the basis for design of on-line computing services.

Morrill, C. S. Computer-aided instruction as part of a management information system. Human Factors, 1967, 9, 251-256.

This paper discusses the application of computer-aided instruction as part of a management information system. The computer presents displays which instruct the student on-line to exercise control of the computer system using a typewriter or a lightpen located at the console work station.

Muckler, F. A. and Obermayer, R. W. Information display. International Science and Technology, August, 1965, 44, 34-40.

Displays are intended to provide a human operator with the kind of information that he can transform into useful decisions or control actions. While the technology exists to present qualitative, quantitative, symbolic, and pictorial data, it is not always certain how these forms are best used to assure that the human receiver is getting clear, unambiguous information that can lead to the desired output of the total man-machine system. Man is a unique information processor because he gives meaning to information. But his processing ability is limited by data load and speed stresses to which he adapts remarkably in ways that are not fully understood. The context in which information has value is in a man's head. This context is in a machine only to the degree that some human has put it there as prior contextual rules of how a system should operate. Combining several types of data on one display indicator does not assure the integration of information, which really occurs in the context of man's interpretation of the display. Most display design has suffered from a pre-occupation with hardware, rather than developing better communication with man.

Narvrocki, L. H., Strub, M. H., and Cecil, R. M. Error categorization and analysis in man-computer communication systems. IEEE Transactions on Reliability, 1973, R-22, 135-139.

This paper briefly examines traditional approaches to human reliability and presents a technique which permits the system designer to derive a mutually exclusive and exhaustive set of operator error categories in a man-computer system. These error categories are defined in terms of process failures and provide the system designer with a qualitative index suitable for determining error causes and consequences. The technique is demonstrated, and the utility of the resulting error categories is evaluated in the context of two studies on a military information processing system. The paper concludes with a brief discussion of detectable and non-detectable errors and a suggestion for determining the impact of errors on ultimate system goals.

Neches, R. Intelligent educational dialogue systems. San Diego, California: University of California, San Diego La Jolla Center for Human Information Processing, Report No. 7701, March, 1977.

This paper describes a hypothetical computer program capable of emulating the behavior of a human tutor. Such a program must ideally, display a number of characteristics. It must be mixed-initiative, meaning that either student or tutor may initiate an interaction. It must be capable of understanding natural language input and generating natural language output. It must be highly knowledgeable about its subject matter, and generative in order to be able to answer unanticipated questions. Finally, the system must be flexible enough to detect the needs of a student and alter its teaching strategy so as to best meet those needs. The first part of the paper discusses what the major parts of the system would be, the functions each part would carry out, and the means by which they interact. The goal is to develop a general system that can be used with a number of different teaching strategies. The second part of the paper analyzes the Socratic teaching method in order to determine the requirements for implementation within the system.

Nickerson, R. S. Man-computer interaction: A challenge for human factors research. Ergonomics, 1969, 12 (4), 501-517.

This paper claims that the increasing heterogeneity of the community of computer users poses a challenge to psychologists and human factos researchers. There follows a brief discussion of why this challenge apparently has not yet evoked a strong response. Three problems, or problem areas, are identified as being particularly in need of human factors research. These are (1) the development and evaluation of conversational languages, (2) the determination of how the use patterns adopted by users depend on system characteristics, and (3) the description, or modeling, of man-computer interaction.

Nickerson, R. S., Elkind, J. I., and Carbonell, J. R. Human factors and the design of time sharing computer systems. Human Factors, 1968, 10, 127-134.

The advent of computer time sharing poses an extraordinary challenge to human factors research during the next decade. Before time sharing, two facts combined to de-emphasize the importance of human factors considerations in the design of computer systems: (1) the cost of the computer's time was exorbitantly high relative to the cost of users' time, and (2) the users constituted a select, highly skilled and highly motivated group of specialists. Two of the promises of time sharing, however, are (1) a drastic reduction in the cost of computer time to the individual user, and (2) the large scale availability of computer facilities to individuals untrained in any areas of computer technology. Human factors considerations then become important both for economic and psychological reasons. This paper briefly notes what a few of these considerations are.

Obermayer, R. W. Accuracy and timeliness in large-scale data-entry subsystems: Proceedings of the 21st annual meeting of the Human Factors Society. Santa Monica, California, Human Factors Society, October, 1977.

Errors generated at the input to automated information systems threaten the utility of the outputs produced by such systems--i.e., the classic GIGO (Garbage In--Garbage Out) problem. Large amounts of effort and attendant costs are involved in dealing with these errors once they are in the system; however, more attention should be given to a coordinated solution of the problem at the source-- the data entry point. A large-scale data-entry subsystem model is presented, together with statistics on error and timeliness. The concept of a Source Data Entry Module (SDEM) is presented along with considerations of design criteria and a design approach. An example is given, paralleling a testbed for which data collection is planned. It is suggested that a generalized SDEM design may be achieveable, providing a basis for the solution of a wide range of automated information system data entry problems.

Palme, J. Interactive software for humans. Stockholm, Sweden: Research Institute of National Defense, Report No. FOA-C10029-M3(E5), July, 1975.

Which of the human needs that are affected by the use of computers? How will computers affect the humans using them? What kinds of communications between humans will the computers cause? How can computer systems be designed to better satisfy human needs? What design principles should be used for such systems? What kinds of man-machine interaction will better satisfy human needs? This paper discusses these problems and presents various methods. Computer driven, command driven and natural language interaction is discussed.

Parsons, H. M. The scope of human factors in computer-based data processing systems. Human Factors, 1970, 12, 165-175.

Work in human factors encompasses research and application in human engineering, procedure development, training techniques, personnel requirements, test and evaluation, task description, and task allocation. Opportunities and needs exist in computer-based data processing systems for all these endeavors, especially with regard to on-line users. Within human engineering, only manual entry has so far received much research attention. Work is also needed on displays, integrated entry-display, workspace and other equipment aspects, on-line languages, and program production. Of greatest concern to human engineering is the computer output, designed by programmers, rather than the hardware. Human factors people will have to master a new field and provide guidance to a new discipline which has not yet understood human factors requirements.

Paulson, B. C., Jr. Continuing research in the development of interactive man-computer systems for engineering-construction projects. Stanford, California: Stanford University, Department of Civil Engineering, Report No. TR-200, September, 1975.

This report describes research employing an interactive man-computer environment to develop, implement and test hypotheses and systems involving integrated network models for the planning and control of resources and operations on large engineering-construction projects. Such analytical systems and procedures are urgently needed for planning and controlling increasingly large and complex engineering and construction projects. Examples include rapid transit systems, nuclear power plants, and mining developments. Specific objectives included: (a) Continue development of promising analytical algorithms and procedures. (b) Implement systems and hardware for communications at the man-computer interface to integrate the project engineers' experience, judgment and qualitative analysis directly into the problem-solving process. (c) Minimize the feedback time required to get information to decision makers for control purposes. (d) Develop objective means to evaluate alternatives in planning and control subsystems.

Peace, D. M. S. and Easterby, R. S. The evaluation of user interaction with computer-based management information systems. Human Factors, 1973, 15, 163-177.

The paucity of human factors work in computer system design is noted, and reasons for this are elaborated with particular reference to computer-based management information systems. The main obstacle to such human factors endeavor would appear to be the lack of appropriate investigatory techniques. To remedy this deficiency a method is proposed which derived from the field of psychotherapy. Pilot studies are reported which demonstrate the technique and indicate how the data obtained may be interpreted. An appraisal of the potential of this technique in the management information system field is presented.

Pew, R. W., Rollins, A. M., and Williams, G. A. Generic man-computer dialogue specification: An alternative to dialogue specialists. Proceedings of the International Ergonomics Association, 6th Annual Congress, College Park, Maryland, July, 1976, 251-254.

It has long been argued that man-computer dialogues should be written by user-oriented human factors specialists rather than by systems designers who were once programmers and who tend to think like programmers. The difficulty is that very few human factors specialists have access to the dens of systems designers and even when their usefulness is recognized there are not enough such specialists to meet the need. This paper will report on an alternative procedure in which the human factors input is made at the stage at which system planning is under way, when system characteristics are sufficiently well defined that it is possible to write a dialogue specification, but before systems designers have begun to write dialogues. If this specification is effective, it will give the designer freedom to do what he does best, but will do it within predefined constraints that will promote the development of an effective interactive system. In conjunction with the development of a large-scale system proposed by the Agricultural Stabilization and Conservation Service such a set of dialogue specifications was written. The specifications would permit several system design teams to work independently, but produce dialogue that is relatively uniform from subsystem to subsystem and that meets standards for good human factors design. The steps undertaken to create the specification are described together with selected samples of the kind of dialogue that may result.

Press, L. Toward balanced man-machine systems. International Journal of Man-Machine Studies, 1971, 3, 61-73.

This paper begins with a simple classification scheme for man-machine systems in which the question used for classification is: Which partner is giving instructions and which one is executing them? A brief survey of current systems and development work shows that little is being done with "balanced" systems, that is those where both partners are active, where either may suggest operations or execute them, and where the order of the steps in the problem-solving process is jointly determined. One strategy for developing a balanced system is to extend a machine-only system to allow for interaction with and participation by a man, who must be enabled to input decisions and to request information to help him make those decisions. This strategy is useful for problems which can be automated, but where all of the information known to the investigator cannot be represented explicitly or where routines to process it economically cannot be invented. Examples are given of the potential application of the approach to simulation studies.

Purdue Laboratory for Applied Industrial Control. Significant accomplishments and documentation of the International Purdue Workshop on Computer Systems. Part III. Development of interfaces and data transmission, in man-machine communications and in the safety and security of industrial computer systems. Lafayette, Indiana: Purdue University, Laboratory for Applied Industrial Control, January, 1977.

This volume represents Part 3 of a six volume set reproducing the major work accomplished by the International Purdue Workshop on Industrial Computer Systems during the past eight years. This material is reprinted from the Minutes of the several individual meetings of the Workshop and represents the work carried out by the standing committees of the Workshop.

Purdue Laboratory for Applied Industrial Control. Significant accomplishments and documentation of the International Purdue Workshop on Industrial Computer Systems. Part VI. Guidelines for the design of man/machine interfaces for process control. Lafayette, Indiana: Purdue University, Laboratory for Applied Industrial Control, January, 1977.

This volume represents Part 6 of a six volume set reproducing the major work accomplished by the International Purdue Workshop on Industrial Computer Systems during the past eight years. This material is reprinted from the Minutes of the Workshop and represents some of the work carried out by the Man/Machine Communications Committee of the Workshop.

Ramsey, P. H., Atwood, M. E., and Van Doren, J. R. A comparative study of flowcharts and program design languages for the detailed procedural specification of computer programs. Alexandria, Virginia: U. S. Army Research Institute for the Behavioral and Social Sciences, Army Research Institute Technical Paper, in press.

This experimental study was performed in an attempt to assess the relative merits of Program Design Languages (PDLs) and flowcharts as techniques for the development and documentation of detailed designs for computer programs. Twenty students in a computer science graduate course participated in an experiment. Working individually, the students designed a two-pass assembler for a simple minicomputer. Half the students expressed their design for the first pass of the assembler in the form of a flowchart, and expressed their design for the second pass in a Program Design Language. The other half of the students used a PDL for pass one, and a flowchart for pass two. Flowcharts and PDLs were compared on the basis of various measures of overall design quality, design errors, level of detail of designs, time expended in developing designs, and subjective preferences. Having completed this design task, the subjects then performed an implementation task. They were given fairly detailed procedural designs for a program which simulates the function of a fairly sophisticated minicomputer. They were then required to develop a working version of the program in PL/1. Although the designs were logically equivalent, half the students received their simulator design in flowchart form, and half in PDL form. Flowcharts and PDLs were compared on the basis of design comprehension test performance, various measures of overall implementation quality, implementation errors, and subjective preference. In the context in which this study was performed, the use of a Program Design Language (PDL) by a software designer, for the development and description of a detailed program design, produced better results than did the use of flowcharts. Specifically, the designs appeared to be of significantly better quality, involving more algorithmic or procedural detail, than those produced using flowcharts. In addition, flowchart designs exhibited considerably more abbreviation and other space-saving practices than did PDL designs, with a possible adverse effect on their readability. When equivalent, highly readable designs were presented to subjects in both PDL and flowchart form, no pattern of short-term or long-term differences in comprehension of the design was observed. No significant differences were detected in the quality or other properties of programs written as implementations of the designs. Subjective ratings indicated a mild preference for PDLs. Overall, the results suggest that software design performance and designer-programmer communication might be significantly improved by the adoption of informal Program Design Languages, rather than flowcharts,

as a standard documentation method for detailed computer program designs.

Reisner, P. Use of psychological experimentation as an aid to development of a query language. IEEE Transactions on Software Engineering, 1977, SE-3 (3), 218-229.

This paper describes a series of psychological experiments used to test a new data base query language. The intent is to make psychological testing of a language part of the design and development process. By testing a language while it is still under development, features that require changing can be identified and the changes made. The experiments, which used college students as subjects, investigated: 1) overall "learnability" of the language, 2) "learnability" of individual features of the language, and 3) the types and frequencies of errors made. Recommended changes to the particular language and the basis for those recommendations are described. In addition, errors made by experimental subjects during the testing are then analyzed from the point of view of possible causes. Based on this analysis, a preliminary model of query writing and two possible indices of query complexity are suggested.

Rijnsdorp, J. E. and Rouse, W. B. Design of man-machine interfaces in process control. In Van Nauta Lemke (Ed.) Digital computer applications to process control. New York: IFAC and North-Holland Publishing Company, 1977, 705-720.

Computerized CRT-displys are rapidly being introduced into man-machine interfaces for process control and supervision. The flexibility of these devices can promote the incorporation of human factors in interface design. This paper gives a survey of design criteria and guidelines for: Allocating system functions between "man" and "machine"; coping with operator skills; evaluating CRT-displays and choosing controls and dialogue structures for these CRT-displays type of displays. Also, attention is paid to experimental comparison of design alternatives, and to the influences of the human organization, high mental stress and job satisfaction on interface design.

Pingel, S., Vicino, F. L., and Andrews, P. S. Human factors research in command information processing systems. Washington, D. C.: Army Personnel Research Office, Report No. APRO-TRR-1145, March, 1966.

The report describes the scope, rationale, organization, and progress of a command systems research program to provide human factors information needed for performance within complex automated information processing systems. Following a survey of military information processing equipment and operations and future plans for command information processing systems, basic human factors problems were identified and organized around five critical operations--screening incoming data, transforming raw data for input into storage devices, input, assimilation of displayed information, and decision making. A research program was formulated and studies undertaken to yield empirical information about the effects on human performance of (1) characteristics of the information presented (density, amount, etc.); (2) dynamic aspects of information (type, extent, coding of updates); (3) display modes and sensory modalities (group vs individual displays, multisensory displays); and (4) computer aids to the decision process. A Command Systems Laboratory was developed to permit simulation of various TOS functions. Findings have suggested the possibility of reduction in storage capacity requirements, number of displays called from storage during a given operational time period, and time required for the total information assimilation-decision process and supported the incorporation and use of information conspicuity coding capabilities in command systems.

Root, R. T. and Sadacca, R. Man-computer communication techniques: Two experiments. Human Factors, 1967, 9, 521-528.

Two experimental studies are reported that were intended to evaluate man-computer communication techniques within the context of the computer-based image interpretation facility. The first experiment, comparing five different data entry procedures, indicated that, although a procedure requiring the interpreter to enter report data directly using a teletype keyboard resulted in the shortest overall throughput time, a procedure involving message composition by the image interpreter with subsequent transcription by a communicator minimizes the time spent by the interpreter in report generation and maximizes the time available for the detection and identification of targets on aerial imagery. The second experiment, evaluating alternative word form-data entry format combination, showed no differences among the six combinations studied.

Roscoe, S. N. Airborne displays for flight and navigation. Human Factors, 1968, 10, 321-332.

This paper deals with certain types of airborne displays, specifically, those used in navigating and flying aircraft. Consideration is given to the nature of the crew's flight task, to certain principles of flight display, and to some of the experimental evidence bearing on principles of display.

Roscoe, S. N. Assessment of pilotage error in airborne area navigation procedures. Human Factors, 1974, 16, 223-228.

In 1969, by specifically including "pilotage error" in the error budget for area navigation system certificaton, the Federal Aviation Administration legally attached economic premiums and "penalties to" human, as well as equipment, performance in man-machine system design. To establish the accuracy of use and freedom from pilot blunders associated with systems employing various configurations of displays and controls requires both simulator and flight experimentation. An automatically adaptive cockpit side task provides a saturating level of pilot workload and allows the sensitive, orderly, and statistically reliable measurement of a pilot's residual attention as a common metric for area navigation system assessment.

Roscoe, S. N. and Eisele, J. E. Integrated computer-generated cockpit displays. In T. B. Sheridan and G. Johnson (Eds.) Monitoring behavior and supervisory control. New York: Plenum Press, 1976, 39-50.

In the new generation of high-speed, multi-mission aircraft the role of the pilot has changed substantially. New system elements typically require the man to be an information manager or a fast decision maker as opposed to a direct controller of flight variables. Adjustment to the new demands has been greatly assisted by innovations in display and control technology and the inclusion of advanced computers on board. These innovations have increased the degree of freedom in function allocation and display and control system design. Yet, to capitalize on these opportunities, further improvements in sensing and display are necessary for a wise use of these additional degrees of freedom. As aircraft become more sophisticated and their missions more demanding, there is an inevitable increase in the pilot's dependence on artificial devices for sensing and display of information about aircraft performance and for control of the aircraft in flight. One approach is to determine the specific information requirements for a particular flight in a particular aircraft and to judge the adequacy of a particular display against these. However, such an approach requires eternal iteration, and there is no way of assuring that all likely missions for any given airplane will be provided for in anything like an optimum manner. A more systematic approach is needed. To succeed in applying modern technology to long-standing unsolved flight management and control problems, what is known from research and experience in specific contexts must first be abstracted through analysis and then integrated through synthesis. Even if all of the pilot's information requirements were exhaustively known, and the required dynamics for each displayed variable specified quantitatively, creative design would still be called for to embody those requirements in a clearly encoded display. The transformations between information to be displayed and its optimum coding remain obscure because lists of information requirements do not imply anything about the relationships among items of information. Information should be considered as an organic, dynamic system, not as discrete items.

Rothenberg, J. An intelligent tutor: On-line documentation and help for a military message service. Marina del Rey, California: Marina del Rey Information Sciences Institute, Report No. ISI/RR-74-26, May, 1975.

The military message service porposed by ISI's Information Automation project is designed to provide full documentation, help, and error-reporting facilities on-line. The Tutor serves these functions by accessing a documentation (or Help) data base which contains multilevel descriptions for every "semantic entity" used in the interface between the service and the user. These descriptions are expandable with respect to the amount and type of information presented, as well as with respect to the user's level of proficiency and experience, as indicated by a User Profile. The Tutor also provides a facility for on-line computer-aided instruction. It can be invoked explicitly by the user's request for help, or by the Command Language Processor and User Monitor in response to unrecognized commands, inefficient operation, or error conditions.

Rouse, S. H. and Rouse, W. B. Design of a model-based on-line management information system for interlibrary loan networks. Champaign, Illinois: University of Illinois at Urbana-Champaign, Coordinated Science Laboratory, Report No. T-54, December, 1977.

The primary purpose of this report is to discuss a study of the feasibility of implementing a model-based online management information system within the Illinois Library and Information Network. To that end, a prototype design is discussed. This discussion includes consideration of the projected operating costs of the management information system. Several issues were considered in developing the prototype design presented here. While many of the issues are discussed in presenting the prototype design, the authors felt that these issues should be given fuller treatment. Thus, a substantial portion of this report reviews the general issues and how they are considered in the literature.

Rouse, W. B. A model of the human in a cognitive prediction task. IEEE Transactions on Systems, Man, and Cybernetics, 1973, SMC-3, 5, 473-477.

The human decision maker's behavior when predicting future states of discrete linear dynamic systems driven by zero-mean Gaussian processes is modeled. The task is on a slow enough time scale that physiological constraints are insignificant compared with cognitive limitations. The model is basically a linear regression system identifier with a limited memory and noisy observations. Experimental data are presented and compared to the model.

Rouse, W. B. Design of man-computer interfaces for on-line interactive systems. Proceedings of the IEEE, 1975, 63 (6), 847-857.

An attempt is made to integrate a wide range of material into a conceptual structure for the design of man-computer interfaces for on-line interactive systems. Typical roles for the human in man-computer systems are considered. Suggestions for the design of systems are developed in discussions of displays and input devices, visual information processing, and mathematical models of human behavior. Possible developments and avenues of research in man-computer systems are suggested.

Rouse, W. B. A model of the human as a suboptimal smoother. IEEE Transactions on Systems, Man, and Cybernetics, 1976, SMC-6 (5), 337-343.

Estimation theory is used to develop a model of a human decision maker in a self-paced, visual data smoothing task. The model is basically a noisy fixed-point smoother combined with a weighting function that discounts data in relation to its distance (in time) from the point being smoothed. Experimental data is used to estimate the parameters of the model. Applications of the model to the design of information displays and man-computer interactive decision making systems are considered.

Rouse, W. B. A model of human decisionmaking in a fault diagnosis task. Proceedings of the Fifteenth Annual Allerton Conference on Control, and Computing, Champaign, Illinois: University of Illinois at Urbana-Champaign, September, 1977.

Utilizing elementary concepts from the theory of fuzzy sets as well as several non-fuzzy heuristics, a model is presented of human decision making in the task of trouble-shooting graphically displayed networks. The performance of the model is compared to the results of two experimental studies.

Rouse, W. B. A theory of human decisionmaking in stochastic estimation tasks. IEEE Transactions on Systems, Man, and Cybernetics, 1977, SMC-7 (4), 274-283.

Human decisionmaking in stochastic estimation tasks is considered. Theoretical and experimental results from mathematical psychology are reviewed. Concepts from stochastic estimation theory are used to develop a theory of human decisionmaking that employs optimal stochastic estimators with a short-term memory model, at least one long-term model, and a method of trading off estimates derived from each model. Approaches to testing the theory as well as the theory's implications are discussed. Also, the limitations of a linear theory are considered.

Rouse, W. B. Human-computer interaction in multitask situations. IEEE Transactions on Systems, Man, and Cybernetics, 1977, (5), 384-392.

Human-computer interaction in multitask decisionmaking situations is considered, and it is proposed that humans and computers have overlapping responsibilities. Queueing theory is employed to model this dynamic approach to the allocation of responsibility between human and computer. Results of simulation experiments are used to illustrate the effects of several system variables including number of tasks, mean time between arrivals of action-evoking events, human-computer speed mismatch, probability of computer error, probability of human error, and the level of feedback between human and computer. Current experimental efforts are discussed and the practical issues involved in designing human-computer systems for multitask situations are considered.

Rouse, W. B. Human problem solving performance in a fault diagnosis task. IEEE Transactions on Systems, Man, and Cybernetics, 1978, SMC-8 (4), 258-271.

It is proposed that humans in automated systems will be asked to assume the role of troubleshooter or problem solver and that the problems which they will be asked to solve in such systems will not be amenable to rote solution. The design of visual displays for problem solving in such situations is considered, and the results of two experimental investigations of human problem solving performance in the diagnosis of faults in graphically displayed network problems are discussed. The effects of problem size, forced-pacing, computer aiding, and training are considered. Results indicate that human performance deviates from optimality as problem size increases. Forced-pacing appears to cause the human to adopt fairly brute force strategies, as compared to those adopted in self-paced situations. Computer aiding substantially lessens the number of mistaken diagnoses by performing the bookkeeping portions of the task.

Rouse, W. B. and Enstrom, K. D. Human perception of the statistical properties of discrete time series: Effects of interpolation methods. IEEE Transactions on Systems, Man, and Cybernetics, 1976, SMC-6 (7), 466-473.

The human's ability to estimate the mean and standard deviation of discrete time series is discussed. The effect of polynomial interpolation formulas on these two statistics is considered both mathematically and experimentally. Derivations show that the piece-wise continuous functions resulting from polynomial interpolation have unbiased expected values and biased variances. Results of two experiments are presented that support the idea that humans base their perceptions on the piece-wise continuous result of interpolation and thereby transmit the statistical bias. The practical implications of these results are discussed.

Samet, M. G. and Davis, K. B. Computer-based supervisory system for managing information flow in C3 systems: Pacing model. Woodland Hills, California: Perceptronics, Report No. PTB-1033-77-3, March, 1977.

This report describes progress on work centered on the demonstration of a system of integrated on-line adaptive user models designed to automatically select and pace information in a simulated command, control, and communication (C3) system. The report includes: (1) a human-factors based rationale for improving information flow in C3 systems; (2) a description of modifications made to the Tactical and Negotiations Game (TNG) scenario to create a C3 decision simulation in which automatic selection and pacing of information can be realistically accomplished; (3) the conceptual specification of a real-time, computer-based model for automatically adapting message pacing rate to the information processing and decision making capabilities of an individual operator; (4) an overview of the software configuration being implemented to support the system. The next phase of work will focus on the system implementation of the newly developed configuration of information selection and pacing models.

Samet, M. G., Weltman, G., and Davis, K. B. Application of adaptive models to information selection in C3 subjects. Woodland Hills, California: Perceptronics, Report No. PTR-1033-76-12, December, 1976.

This report describes research and development centered on the demonstration of an on-line adaptive model for automatically selecting information in a command, control, and communication (C3) system. Rationale for application of the model is built upon a review of psychological literature concerning human performance in specifying information requirements, and in acquiring and utilizing information for military decision making. Based on a multi-attribute decomposition of information messages, the model selects information for an individual user according to his observed information preferences in response to specific situational requirements. An additional algorithm reduces the size of a selected information set by dynamically pruning relatively low-utility items. The model was implemented for a simulated ASW tracking task, and was systematically evaluated in terms of both its intrinsic performance and the performance of an expert operator working with it. The results demonstrated the capability of the model to adapt to varied individualized information seeking strategies, and to subsequently automate the selection of information appropriate to those strategies. Empirical evaluations showed that an operator was able to perform the tracking task successfully and much more rapidly with automatic selection of information. Moreover, performance effectiveness was enhanced by the removal of messages which contributed little to the overall utility of an information set. The findings are discussed in terms of the advantages and implications of the adaptive, multi-attribute utility model and its potential application for improving information flow (e.g., pacing and routing) and utilization in computer-based C3 systems.

Schank, R. C. Research at Yale in natural language processing. New Haven, Connecticut: Yale University, Department of Computer Science, Report No. RR-84, 1976.

This report describes the state of the computer programs at Yale that do automatic natural language processing as of the end of 1976. The theory behind the programs shown here as well as descriptions of how those programs function has been described elsewhere. This report summarizes the capabilities of 5 computer programs at the present time.

Schneiderman, B. and McKay, D. Experimental investigations of computer program debugging and modification. Proceedings of the 6th Congress of the International Ergonomics Association. Human Factors Society, College Park, Maryland, July, 1976.

Although greater emphasis is placed on the task of computer program composition, debugging and modification often consume more time and expense in production environments. Debugging is the task of locating syntactic and semantic errors in programs and correcting these errors. Modification is the change of a working program to perform alternate tasks. The factors and techniques which facilitate debugging and modification are poorly understood, but are subject to experimental investigation. Controlled experiments can be performed by presenting two groups of subjects with two forms of a program or different programming aids and requiring the same task. For example, in one study we presented an 81 line FORTRAN program containing bugs to distinct groups of subjects. One of the groups received a detailed flowchart, but results indicated that this aid did not facilitate the debugging procedure. Similar negative results were obtained for a modification task. In other experiments, comments and meaningful variable names were useful in debugging and modularity facilitated modification. Other potentially influential factors, which are subject to experimental study, include indentation rules, type of control structures, data structure complexity and program design. These and other human factor experiments in programming have led to a cognitive model of programmer behavior which distinguishes between the hierarchically structured, meaningfully acquired semantic knowledge and the rotely memorized syntactic knowledge. Errors can be classed into syntactic mistakes which are relatively easy to locate and correct and two forms of semantic mistakes. Semantic errors occur while constructing an internal semantic structure to a representation in the syntax of a programming language. Modification is interpreted as the acquisition of an internal semantic structure by studying a program, followed by modification of this structure and revision of the code.

Seibel, P. Data entry devices and procedures. In H. R. VanCott and R. G. Kincade (Eds.) Human engineering guide to equipment design. Washington, D.C.: U.S. Government Printing Office, 1972, 311-344.

A wide variety of alternative means for entering data have accompanied the automation of data handling. These range from keyboards, levers, switches, and dials to light pencils, and handwritten or voice inputs. The speed and accuracy with which data entry is accomplished using these devices depend on (a) the characteristics of the source data, (b) the design of the data entry device, and (c) the characteristics of the operator. This chapter presents recommendations and cross comparisons for the human engineering design or selection of a variety of data entry devices, procedures, and source document formats. Steering wheels and joysticks, which are continuous control data entry devices, are discussed.

Shackel, B. Man-computer interaction - the contribution of the human sciences. Ergonomics, 1969, 12 (4), 485-499.

An introductory survey is presented of the possible contribution of the human sciences to man-computer interaction, based upon a full review of the relevant human factors literature which is to be published. A possible taxonomy for the field is proposed founded on broad divisions of the human sciences problem areas and of the types of computer systems and services. Using the taxonomy as a framework, some examples of relevant human sciences work and some problems and research needs are discussed.

Sheppard, S. B., Borst, M. A., Curtis, B., and Love, L. T. Predicting programmers' ability to modify software. Arlington, Virginia: General Electric Company, Report No. TR-388100-3, May, 1978.

This report describes the second experiment in a program of research designed to identify characteristics of computer software which are related to its psychological complexity. Thirty-six experienced programmers were given unlimited time to make specified modifications to a preliminary program and three experimental programs. The correctness of the modification and the time required to make each modification served as dependent variables. Results indicated that the difficulty of the modification was significantly related to the time to solution. This relationship was described by a hyperbolic function relating time to the number of statements to be inserted in the code. Modest effects on the score and time were observed for order of presentation, suggesting a learning effect. On two of the three programs studied, better modifications were made when the control flow of the original programs was well-structured. No performance effects were related to the absence of comments or the type of comments (in-line versus global) used. Moderate relationships with the criteria were observed for several complexity metrics, and these were stronger where metrics were obtained from the modified code rather than the original programs.

Sheppard, S. B. and Love, L. T. A preliminary experiment to test influences on human understanding of software. Arlington, Virginia: General Electric, Information Systems Programs, Report No. TR-77-388100-1, June, 1977.

Eight experienced programmers were each given three FORTRAN programs to memorize and reproduce functionally, without notes. Three levels of complexity of control flow and three levels of mnemonic variable names were independently manipulated. The experimental design was an incomplete split-plot factorial where each programmer was given one version of each program and all levels of the two primary independent variables. The participants correctly recalled significantly more statements when the complexity of control flow was reduced. Differences in recall for the three levels of mnemonic variable names were not significant. A further analysis compared the percent of statements correctly recalled to Halstead's E, a measure of the effort required to code a program. The Pearson correlation coefficient was -0.81, over the 24 data points; thus indicating that Halstead's E is a powerful predictor of one's ability to understand a computer program. Several changes in the experimental design and the conduct of the experiment itself are recommended for future experimental work in this area.

Sidorsky, R. C. Alpha-Dot: A new approach to direct computer entry of battlefield data. Arlington, Virginia: U.S. Army Research Institute for the Behavioral and Social Sciences, Technical Paper 249, January, 1974.

The Alpha-dot system is a coding technique that enables people to input data using familiar shapes in a form that is also directly compatible with computers and other binary data processors. The technique can be used as the basis for a number of devices and procedures for two-way communication of information between man and machine. For example, data can be input via keyboards, pressure sensitive "tablets," CRT's, paper forms and other means. The purpose of the present research was to determine the suitability of the 5 key Alpha-dot keyboard for source data automation of battlefield information. Ten enlisted personnel entered both free form and formatted versions of simulated enemy situation spot reports. Learning time as well as rate and accuracy of data entry using the Alpha-dot keyboard was compared to operator performance using a standard typewriter. No special skill is required to operate the device. All of the trainees were able to input messages satisfactorily after two or three minutes of instruction. Learning time for skilled operation is very short. Nine of the ten trainees memorized the character set within 1 1/2 hours of practice and were then able to transmit messages without reference to the guide chart. Rate of data entry compares favorably with the standard keyboard. After less than five hours of practice, free text messages were entered at 60% of each trainee's standard keyboard rate. However, formatted (TOS type) messages were transmitted at a rate equal to or exceeding that of the standard keyboard. Uncorrected errors were nil with both keyboards. The Alpha-dot technique appears to have potential as a means of increasing the speed, accuracy and flexibility of input of battlefield data by frontline observers.

Smith, E. E., Shoben, E. J., and Rips, L. J. Structure and process in semantic memory: A feature model for semantic decisions. Psychological Review, 1974, 81, 214-241.

A model is proposed to account for recent findings on the time needed to decide that a test instance is a member of a target semantic category. It is assumed that the meaning of a lexical term can be represented by semantic features. Some of these features are essential or defining aspects of a word's meaning (defining features), while others are more accidental or characteristic aspects (characteristic features). This defining versus characteristic distinction is combined with a two-stage processing mechanism in such a way that the first stage determines the similarity between the test instance and target category with respect to both defining and characteristic features, while the second stage considers only agreement between defining features. This model is shown to be consistent with most semantic memory effects, and two new experiments provide further detailed support for it.

Smith, S. L. and Goodwin, N. C. Computer-generated speech and man-computer interaction. Human Factors, 1970, 12, 215-223.

Large-scale use of talking computers may be anticipated for reasons of general convenience and special effectiveness. A telephone link to a computer, with touch-tone inputs and stored speech outputs poses a number of design problems of interest for the human factors specialist. Recommended features include (1) user pacing and optional repetition of speech output in a transactional sequence, (2) use of different voices and other auditory coding to distinguish types of output, and (3) use of tone codes to indicate required input.

Smolyan, G. L. Development of man-computer interaction. Arlington, Virginia: Joint Publications Research Service, May, 1973.

This report discusses the problem of interaction between man and computers as a primary factor in raising the efficiency of man-machine systems of control and data processing.

Snyder, H. L. Image quality and face recognition on a television display. Human Factors, 1974, 16, 300-307.

Subjects were asked to match faces presented singly on a television display with one of 35 faces presented on a photographic display. The probability of correct recognition and the time required to recognize the single face were related to the quality of the television image. Image quality was varied by changing the squarewave response of the television system and the video signal-to-noise voltage ratio. A derived unitary metric of image quality, the square-wave modulation transfer function area, MFTA , was shown to correlate highly with both measures of observer performance. The utility of this metric for systems design is discussed.

Sperandio, J. C. and Bisseret, A. Human factors in the study of information input devices. Farnborough, England: Royal Aircraft Establishment, Report No. RAE-LIB-TRANS-1728, BR41239, March, 1974.

One problem area in man-machine system is that of communication between man and machine. A good knowledge of the various communication devices and of their compatibility with the operator is therefore very useful when preparing the optimization of a working system. Keyboard and comparisons based on speed, accuracy, ease of training, users convenience are considered following, as a guideline, the development of input devices to permit higher speeds. The implications of parallel inputs (chord playing keyboards) and the consequent loss of flexibility are considered. Other non-keyboard systems are dealt with and some speculation as to usefulness of devices permitting perception and decoding of natural language is presented.

Spesock, G. J. and Lincoln, R. S. Human factors aspects of digital computer programming for simulator control. Human Factors, 1965, 7, 473-482.

Because of the enormous present day effort devoted to the preparation of digital computer programs, special attention should be given to the human factors aspects of program development. Currently available program compilers represent a significant application of certain human factors principles, but are not generally applicable to problems of "real time" programming. Since the creation of appropriate compilers is important to simulation methodology, this report includes a detailed description of a "real time" compiler developed for display/control simulation on a small computer in a human factors laboratory.

Steeb, R., and Artof, M., Crooks, W. H., and Weltman, G. Man-machine interaction in adaptive computer-aided control: Final report. Woodland Hills, California: Perceptronics, Report No. PATR-1008-75-12/31, December, 1975.

Shared decision making between man and intelligent machine is becoming an important part of advanced systems. The research described in this paper is directed toward developing human factors criteria for the man/machine interaction. The research effort include evaluations of task allocation techniques, information feedback, and decision analysis methods. The report presents the results of a series of experimental investigations of adaptive computer aided control. The report includes (1) a review of shared decision making and control with intelligent machines; (2) an analysis of decision processes and performance in shared control tasks; (3) a description of a representative shared control simulation involving remotely piloted vehicle guidance; and (4) a series of experiments centering on methods of automatic control allocation and feedback. The results of the investigation suggest that automatic allocation of control based on estimated operator utilities or on objectively defined values is of advantage in shared control. The choice of allocation criteria and feedback type both depend strongly on the situation. Performance (objective value) based allocation and feedback resulted in control proportions closer to the optimum amount than preference based on allocation.

Steeb, R., Weltman, G., and Freedy, A. Man/machine interaction in adaptive computer-aided control: Human factors guidelines. Woodland Hills, California: Perceptronics, Report No. PATR-1008-76-1/31, January, 1976.

This report provides in guideline form a summary of the investigation, findings and recommendations compiled in a series of studies of adaptive computer aided control. These studies, spanning the four year period from November 1971 to November 1975, were directed toward developing human factors criteria for the interaction between man and intelligent machine. The areas considered include: (1) the range of application of adaptive aiding, (2) characteristics of adaptive control systems, (3) allocation of control function, (4) man/machine communication, (5) operator selection and training, and (6) system performance analysis methods.

Strub, M. H. Evaluation of man-computer input techniques for military information systems. Washington, D. C.: U. S. Army Behavior and Systems Research Laboratory, Technical Report 226, May, 1971.

The accuracy and speed of two input procedures were each compared under two conditions of verification. In one procedure, the incoming message is translated onto a paper format before being transcribed on a CRT screen (off-line). In the other, the message is translated directly on the CRT screen (on-line). In the unverified condition, one man performs the input operation without error check; in the verified condition, two men translate the same message and compare their translations before entering the information into the data base. Results under the four experimental conditions were also compared with a procedure similar to that used in the 7th Army TOS in which a message is translated onto a paper format and the unverified message is copied on the CRT screen by the operator of a user input output device (UIOD). Subjects were 60 enlisted men studying at the USMA Prep School, who were divided into four groups and assigned to the four experimental conditions so as to furnish data for analysis of variance. There were significantly fewer errors when the message was input directly on the CRT than when paper formats were used as an intermediate step (11.2% error vs 14.8%). Speed of input was practically the same under the two methods. When two operators checked each other's translations before the information was entered into the data base, error was reduced by one third (10.3% vs 15.7%), but the procedure took about one-third more time (6.81 min. vs 4.98 min.). Either procedure was an improvement in accuracy over the work method of having the message translated onto a paper format by one "action officer" and then having a UIOD operator copy the format on the CRT and then enter the format into the data base. The present research strongly suggests that incoming messages should be translated directly on the CRT screen. Direct CRT input would reduce error while eliminating paper formats and need for the UIOD operator to transcribe the paper formats on a CRT screen -- A considerable saving in effort and materials. While verification by a second operator substantially reduces the number of errors entering the system, a tradeoff against time and manpower must be reckoned with. Present findings suggest that, when time and personnel permit, messages should be verified for consistency before the information is entered into the data base.

Strub, M. H. Automated aids to on-line tactical data inputting. Washington, D. C.: U. S. Army Behavior and Systems Research Laboratory, Technical Report 262, February, 1975.

In an automated information system the input operator must convert free text information into computer-readable format rapidly and accurately as he enters it into the data base. This report describes and evaluates a computer-assisted message inputting (CAMI) aid designed to provide useful additional formatting instructions to operators. Both a full format and an experimental checklist format were used with the CAMI CRT and with a handbook of instructions and sample formats to input scenario-type messages. Subjects were 60 enlisted men divided into five groups, one for each of the experimental conditions plus one using only the handbook and blank-screen CRT. Speed and accuracy were measured. Speed did not differ significantly among the four experimental conditions, but the fifth unaided condition was significantly slower. No significant differences in accuracy appeared. However, over 80% of the total input errors were discoverd to be types of error which are not detectable by present automated error-checking routines.

Swartzendruber, L., Ince, F., Williges, R. C. and Roscoe, S. N. Two linear rate-field displays. Human Factors, 1971, 13, 569-575.

An airspeed display and a lateral displacement (runway) display, arranged vertically and horizontally, respectively, were concurrently tracked by relatively inexperienced pilots using a joy stick. On each display the primary indicator was a small band which moved lengthwise. A moire-pattern rate field (RF) moved alongside and with the primary. Each of four experimental conditions included both primary indicators and (a) no rate fields, (b) the airspeed rate field only, (c) the runway rate field only, or (d) both rate fields. Response measures for each display included (a) latency of initial response, (b) control reversals, and (c) root-mean-square (RMS) tracking error. Rate fields decreased RMS error for the runway display. Latency was briefer, but more reversals occurred on the airspeed display than on the runway display. Rate fields apparently serve an attention gathering function, but this cannot be fully investigated until optimum direction-of-motion relations are determined.

Taylor, R. W. Man-computer input-output techniques. IEEE Transactions on Human Factors in Electronics, 1967, HFE-8, 1-4.

In setting the stage for the papers which follow, there is discussion in this paper of some problems of terminology concerning multiple-access, on-line, interactive man-computer systems. It presents three viewpoints from which to examine man-computer interactions. The first viewpoint is one of the internal representation of a problem within a machine. The second is concerned with the nature of the surface structure of the system through which the user and the computer interact. Applications provide the third viewpoint from which man-computer systems must be examined. The remaining seven papers of the issue are briefly discussed. This discussion raises questions of comparative evaluation and quantitative description of man-computer systems. Problems of instrumentation and measurement of man-computer systems are important problems upon which very little work has been done.

Teitelman, W. PILOT: A step toward man-computer symbiosis. Cambridge, Massachusetts: Massachusetts Institute of Technology, Report No. MAC-TR-32, September, 1966.

PILOT is a programming system constructed in LISP. It is designed to facilitate the development of programs by easing the familiar sequence: write some more code, run the program again, etc. As a program becomes more complex, making these changes becomes harder and harder because the implications of changes are harder to anticipate. In the PILOT system, the computer plays an active role in this evolutionary process by providing the means whereby changes can be effected immediately, and in ways that seem natural to the user. The user of PILOT feels that he is giving advice or making suggestions, to the computer about the operation of his programs, and that the system then performs the work necessary. The PILOT system is thus an interface between the user and his program, monitoring both the requests of the user and the operation of his program. The user may easily modify the PILOT system itself by giving it advice about its own operation. This allows him to develop his own language and to shift gradually onto PILOT the burden of performing routine but increasingly complicated tasks.

Thomas, J. C. A method for studying natural language dialogue. Yorktown Heights, New York: IBM Thomas J. Watson Research Center, Behavioral Sciences Group, Computer Science Department, Report No. RC 5882 (#25427), February, 1976.

This report describes progress on an experimental technique for studying application-specific dialogues. In this technique, a user interacts via typed messages with a second person who is simulating a computerized natural language interface. The dialogues are all concerned with order-handling and invoicing: however, they are collected in three different situations. The user is variously attempting to describe, understand, or diagnose an order-handling and invoicing system. Preliminary results indicate some of the ways in which the specific user task (pragmatics) influences dialogue features. The importance and complexity of having a natural language interface understand comments about the communicators and the communication itself as illustrated.

Thomas, J. C. Quantifiers and question-asking. Yorktown Heights, New York: IBM Thomas J. Watson Research Center, Behavioral Sciences Group, Computer Science Department, Report No. RC 5866 (#25388), February, 1976.

Data concerning the use of universal quantifiers in question-asking is presented. These data were collected in a variety of procedures using nonprogrammers. These non-programmers variously translated English questions into a query language, generated their own English questions, translated Venn diagrams into English or vice versa, gave judgements about the consistency of two English statements, or manually looked up answers to questions. Subjects showed considerable difficulty with the logician's notations of set relations (except disjunction) on all tasks. The interpretations given quantified sentences varied between subjects on a given task and even within a subject, between tasks. Generally speaking, subjects gave interpretations consistent with quantified natural language questions or Venn diagrams but not equivalent to them. Subjects used explicit set specifications rarely in spontaneous English.

Thomas, J. C. A design-interpretation analysis of natural English with applications to man-computer interaction. Yorktown Heights, New York: IBM Thomas J. Watson Research Laboratory, Behavioral Sciences Group, Computer Science Department, Report No. RC 6581 (#28392), June, 1977.

Many behavioral scientists and most designers of man-computer interfaces view communication in a certain way. This viewpoint includes the implicit belief that communication from system A to system B essentially involves the encoding of some internal state in system A into an external statement for transmission to system B decodes this message and changes its internal state, Communication is considered 'good' to the extent that there is an isomorphism between the internal states of the two systems after the message has been sent. This paper argues that this view is inadequate both for an understanding of communication between two persons and as a theoretical foundation for any kind of man-computer interaction, particularly in natural language. Empirical results supporting this proposition are reported. In addition, an alternative view of the communication process is outlined. This view stresses the game-theoretic aspects of communication, the importance of viewing message-building as a constructive (rather than translational) process, the importance of metacomments, the multiplicity of channels involved in human natural language communication, and stresses that, under certain conditions, the 'vagueness,' 'fuzziness' and ambiguity of natural language are assets, not liabilities. The paper concludes by discussing some ways these ideas could serve as possible guidelines for the design of man-computer interfaces. A major purpose of the paper is to encourage the expression of alternative views on these issues.

Thomas, J. C. and Gould, J. D. A psychological study of query by example. Yorktown Heights, New York: IBM Thomas J. Watson Research Center, Behavioral Sciences Group, Computer Science Department, Report No. RC 5124, November, 1974.

Thirty-nine non-programmers were taught Zloof's Query by Example system in order to provide behavioral data prior to implementation. This training took less than three hours. Then subjects were given 40 test questions in English which they translated into Query By Example. Subjects also recorded the time to write each query and their confidence about being correct. Sixty-seven per cent of the queries were written correctly. Subjects averaged 1.8 minutes to write queries. Query difficulty could largely be predicted from a linear regression based on objective complexity measures. Confidence rating was also an excellent predictor of query difficulty. Subjects had difficulty with quantification but little trouble with linking variables, conjunctions, or disjunctions. In a two-week re-test, four of six subjects showed nearly perfect retention of the system rules. Recommendations to help prevent certain error types are made.

Topmiller, D. A. Man-machine command-control-communication simulation studies in the Air Force. Wright-Patterson AFB, Ohio: Aerospace Medical Research Laboratory, Report No. AMRL-TR-76-122, 1976.

This paper reviews and summarizes approximately 15 years of man-machine simulation research in command, control and communication systems conducted by this laboratory. Summaries of decision aiding techniques for tactical command decision making conducted at Ohio State University are made. Descriptions and summary findings of C3 simulations for the BUIC III, AWACS, and RPVs are presented. A comparison of results obtained with real-time operator-in-the-loop simulations with computer simulations using a Systems Integrated Network of Tasks (SAINT) model predictions were illustrated to demonstrate the power and utility of iterating computer simulation with real-time simulations.

Treu, S. A computer terminal network for transparent stimulation of the user of an on-line retrieval system, Washington, D. C.: National Bureau of Standards, Report No. NBS-TN-732.

A computer terminal network to enable 'transparent stimulation' of the user of an on-line retrieval system has been designed, implemented, and pilot tested. Its basic purpose is to provide a suitable and effective framework and methodology for experimental identification/validation of those human characteristics which should be recognized/reinforced in man-computer interface design. The rationale behind the transparent stimulation approach is presented and the methodology employed for such real-time, unobtrusive scanning and manipulation of the man-computer dialogue is described. A general overview of the hardware and software features of the implemented stimulation network is included.

Uttal, W. R. "Basic Black" in computer interfaces for psychological research. Behavior Research Methods and Instrumentation, 1968, 1 (1), 35-40.

In this paper we present the specifications of a set of interface components able to connect a digital computer to any of a large number of psychological experiments. We believe this set to be nearly inclusive of most of the needs of current computer controlled psychological research. The function and special requirements of each of the devices is described and a block diagram presented. Specific details of electronics construction are not discussed.

Walther, G. H. The on-line user-computer interface: The effects of interface-flexibility experience, and terminal-type on user-satisfication and performance. Unpublished doctoral dissertation, The University of Texas, Austin, Texas, August, 1973.

There has been a recent recognition by systems designers of the necessity for considering the needs and preferences of the user of on-line computers. Very little empirical evidence exists for guiding 'user-oriented' design efforts. In this study, two levels of interface flexibility, the user's prior experience on-line, and terminal type were investigated as possible determinants of user satisfaction and performance. The task consisted of text correction with an on-line text editor. A general linear models statistical technique controlled for the effects of measurable but uncontrollable variables. Interface flexibility, operationalized as alternatives to the user, is not uniformly effective in producing optimal performance for all users, nor in producing optimal perceptions of satisfaction. An attempt was made to specify the kinds of users for whom flexibility is 'best'.

Williges, R. C. Automation of performance measurement. Symposium proceedings: Productivity Enhancement: Personnel performance assessment in Navy systems, San Diego, California, October 12-14, 1977, 153-167.

Detailed prediction schemes of operator performance do not exist even though there is a widespread requirement for quantitative performance measures throughout the life cycle of personnel systems. Some approaches to quantitative performance measurement are reviewed, and a description of a prototype performance assessment system based on polynomial regression prediction equations is presented. These equations can be used to determine tradeoffs in system design, to optimize personnel performance through the appropriate design of tasks, to isolate potential training requirements, and to provide a comparison standard for assessing personnel readiness in operational systems. In addition, a discussion is provided on the use of an automated performance measurement schema to enhance personnel effectiveness by embedded performance measurement, evolutionary system operation, and the development of appropriate job aids. Several unresolved issues dealing with future analytical and research needs are presented. These issues include the development of a prototype assessment system, an investigation of efficient strategies for data collection, the consideration of the appropriate candidate systems for automated performance measurement, and the cost effectiveness of such measurement systems. It was concluded that current advances in behavioral research methodology now make it feasible to consider the development of a complex, automated performance measurement system. Once this system exists, it can be used to generate a realistic data base of complex human performance from which meaningful generalizations can be made.

Williges, R. C. Experimental designs for investigating human operator/machine systems. Proceedings of the 21st annual meeting of the Human Factors Society, San Francisco, California, October 17-20, 1977, 462-466.

To increase the generalizability of the results, a human factors specialist must consider a large number of factors simultaneously when investigating complex human operator/machine systems. When complex multifactor experiments are necessary, the resulting number of treatment conditions and cost of conducting the study quickly becomes unwieldy if traditional, completely-crossed, factorial designs are used. Several data reduction designs are reviewed as potential alternatives to solve the generalizability/cost dilemma. These alternatives include single observation factorial designs, hierarchical designs, blocking designs, fractional factorial designs, and central-composite designs. Each of these alternatives should be part of a clearly formulated research strategy in which the experimenter efficiently collects data in stages, completes a thorough and careful pretesting, determines the real-world constraints dictated by the research problem, and selects the necessary design modifications based on these real-world constraints.

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